Agriculture Canada

RESEARCH BRANCH REPORT

1988

RAPPORT DE LA DIRECTION GÉNÉRALE DE LA RECHERCHE

Canada

Research Branch Report

1988

Rapport de la Direction générale de la recherche

RESEARCH BRANCH
DIRECTION GÉNÉRALE DE LA RECHERCHE

AGRICULTURE CANADA

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FOREWORD

In 1988, the Research Branch moved forward with implementation of its proposal for action. This document, Part 5 of *Canadian agricultural research and technology transfer: Planning for the future*, outlines the branch plan of action for the next 4 years.

The branch mission is to improve the long-term marketability of agri-food products by decreasing costs of production, increasing the value added to food products through diversification, and placing more emphasis on food safety and environmental quality.

The Research Branch is in business for the long term. Emphasis is on conducting strategic high-risk research, the results of which can have widespread application. We are also paying more attention to the role of the various research performers in the agriculture sector, in order to build a stronger cooperative and coordinated approach to national research efforts.

With our new research strategy in place, we are developing improved planning procedures to ensure effective use of limited resources, including both operating and capital expenditures. Over the past year, three station reviews and 13 program reviews were conducted to streamline programs and operations. Short-term research is directed to satisfying the needs of specific clients, who are involved directly in priority setting, management, and funding. Station advisory committees have been formed at most research establishments to ensure direct participation by our clients. Partnerships and joint ventures are being encouraged, and we have realized considerable success in negotiating agreements with the provinces, universities, and industry.

The recently created Industry Relations Office developed a branch-wide policy framework and strategic plan in 1988. The primary role of this office is to facilitate partnerships with industry, to commercialize branch technology, and to acquire needed foreign science and technology. Also, the national Research Branch Advisory Committee, made up of senior industry officials, met twice during 1988 to advise on our research priorities and programs.

The *Research Branch Report* provides an annual summary of achievements throughout the branch. Detailed results are reported in both scientific and extension-type papers, listed for 1988 at the end of each establishment's report. Information is passed on to producers and food processors through various provincial committees and technology transfer mechanisms.

The Eastern Region, Western Region, and Central Experimental Farm comprise 33 major establishments, 13 experimental farms, and several smaller units. Each one carries out research with national and regional objectives while developing technology that is pertinent to the specific area where it is located. The Eastern Region has responsibility for the establishments in Ontario, Quebec, and the Atlantic Provinces. The Central Experimental Farm consists of six research centres in Ottawa that combine research on national programs with special services to regional establishments and the public. The Western Region has 12 major establishments located in the four western provinces.

The Strategies and Planning Directorate, located at Research Branch Headquarters in Ottawa, has six principal functions. These are Financial Planning and Analysis, Industry Relations, Management Services, Policy Analysis and Planning, and Research Program Service. The Research Coordination Directorate, also located at Research Branch Headquarters, is responsible for the development of national research strategies in the areas of crops, animals, food, and resources.

Research programs in the branch are developed in response to the needs of the agri-food industry, which are determined through the Canadian Agricultural Services Coordinating Committee (CASCC) and by consultations at all levels of the agri-food sector. The branch is responsible for organization of the activities of CASCC and of the Canadian Agricultural Research Council (CARC).

In 1988, the Research Branch had a budget of $245 million and a staff of 3480, of which 939 were professionals.

The Research Branch has ongoing science and technology exchanges with several countries. Scientific and technical information and personnel are provided to development-assistance projects sponsored by the Canadian International Development Agency (CIDA).

This report documents the continuous efforts by Research Branch staff to deliver a broad and effective research program that benefits all sectors of the agri-food industry.

A.O. Olson
Assistant Deputy Minister, Research

AVANT-PROPOS

En 1988, la Direction générale de la recherche est allée de l'avant dans l'application de son *Projet d'activités*. Cet exposé de stratégie décrit le plan d'action qu'entend suivre la Direction générale de 1988 à 1992.

La mission de la Direction générale est d'améliorer le potentiel de commercialisation à long terme des produits agro-alimentaires en réduisant les coûts de production, en augmentant la valeur ajoutée des produits alimentaires par la diversification et en insistant davantage sur la salubrité des aliments et la qualité de l'environnement.

La Direction générale de la recherche travaille à long terme. L'accent est mis sur la réalisation de travaux de recherche stratégiques à risque élevé, dont les résultats peuvent être largement appliqués. Nous accordons également une plus grande attention au rôle des différents exécutants de la recherche dans le secteur agricole afin de mieux concerter les efforts de recherche de la nation.

Forts de notre nouvelle stratégie de recherche, nous sommes en train de perfectionner nos méthodes de planification afin d'utiliser plus efficacement le peu de ressources dont nous disposons y compris les crédits de fonctionnement et d'immobilisation. L'an dernier, on a procédé à l'examen de la situation de trois stations et de 13 programmes afin d'en simplifier et d'en rationaliser le fonctionnement. La recherche à court terme vise à satisfaire aux besoins de certains clients bien précis. Il en résulte une participation nettement plus directe de leur part dans l'établissement des priorités, la gestion et le financement. Des comités consultatifs de stations ont été formés dans la plupart des établissements de recherche pour assurer cette participation directe de notre clientèle. Le partenariat et la coentreprise sont encouragés, et nous avons considérablement progressé dans la négociation d'ententes avec les provinces, les universités et le secteur privé.

Notre Bureau des relations industrielles récemment créé a élaboré un cadre et un plan stratégiques à l'échelle de la Direction générale en 1988. Son rôle premier est d'établir des politiques et des méthodes visant à faciliter le partenariat avec le secteur privé, à commercialiser les techniques mises au point par la Direction générale et à acquérir les sciences et technologies étrangères dont nous avons besoin. De plus, le Comité national consultatif de la Direction générale composé de hauts représentants du secteur privé s'est réuni deux fois en 1988 pour donner son avis sur nos priorités et programmes de recherches.

Le *Rapport de la Direction générale de la recherche* est un résumé annuel des réalisations de la Direction générale. Les résultats ont été publiés dans des articles scientifiques et de vulgarisation. La liste de ces articles pour 1988 se trouve à la fin du rapport de chacun des centres de recherches. L'information est communiquée aux producteurs et aux transformateurs d'aliments par divers comités provinciaux et par des mécanismes de transfert de technologie.

Les régions de l'Est, de l'Ouest et de la Ferme expérimentale centrale comptent 33 grands établissements, 13 fermes expérimentales et plusieurs unités petites. Chacun de ces établissements procède à des travaux de recherche qui poursuivent des objectifs nationaux et régionaux tout en développant une technologie adaptée à sa propre région. La Région de l'Est est responsable des établissements situés en Ontario, au Québec et dans les provinces de l'Atlantique. Celle du Centre, qui compte six centres de recherches à la Ferme expérimentale centrale à Ottawa fait des recherches sur les programmes nationaux et assurent des services spéciaux aux établissements régionaux et au public. La Région de l'Ouest compte 12 grands établissements dans les quatre provinces de l'Ouest.

La Direction des stratégies et de la planification, logée au siège de la Direction générale de la recherche à Ottawa, a six composantes principales, notamment la Planification et analyse financière, les Relations industrielles, les Services de la gestion, l'Analyse politique et de planification et le Service aux programmes de recherche. La Direction de la coordination de la recherche, qui est également située à l'administration centrale de la Direction générale de la recherche, est responsable du développement des stratégies nationales de recherche en ce qui touche les cultures, les animaux, les aliments et les ressources.

Les programmes de recherche de la Direction générale sont conçus pour satisfaire aux besoins du secteur agro-alimentaire, qui sont évalués par le Comité de coordination des services agricoles canadiens (CCSAC) et par des consultations auprès de tous les segments du secteur agro-alimentaire. La Direction générale se charge de l'organisation des activités du CCSAC et du Conseil de recherche agricole du Canada (CRAC).

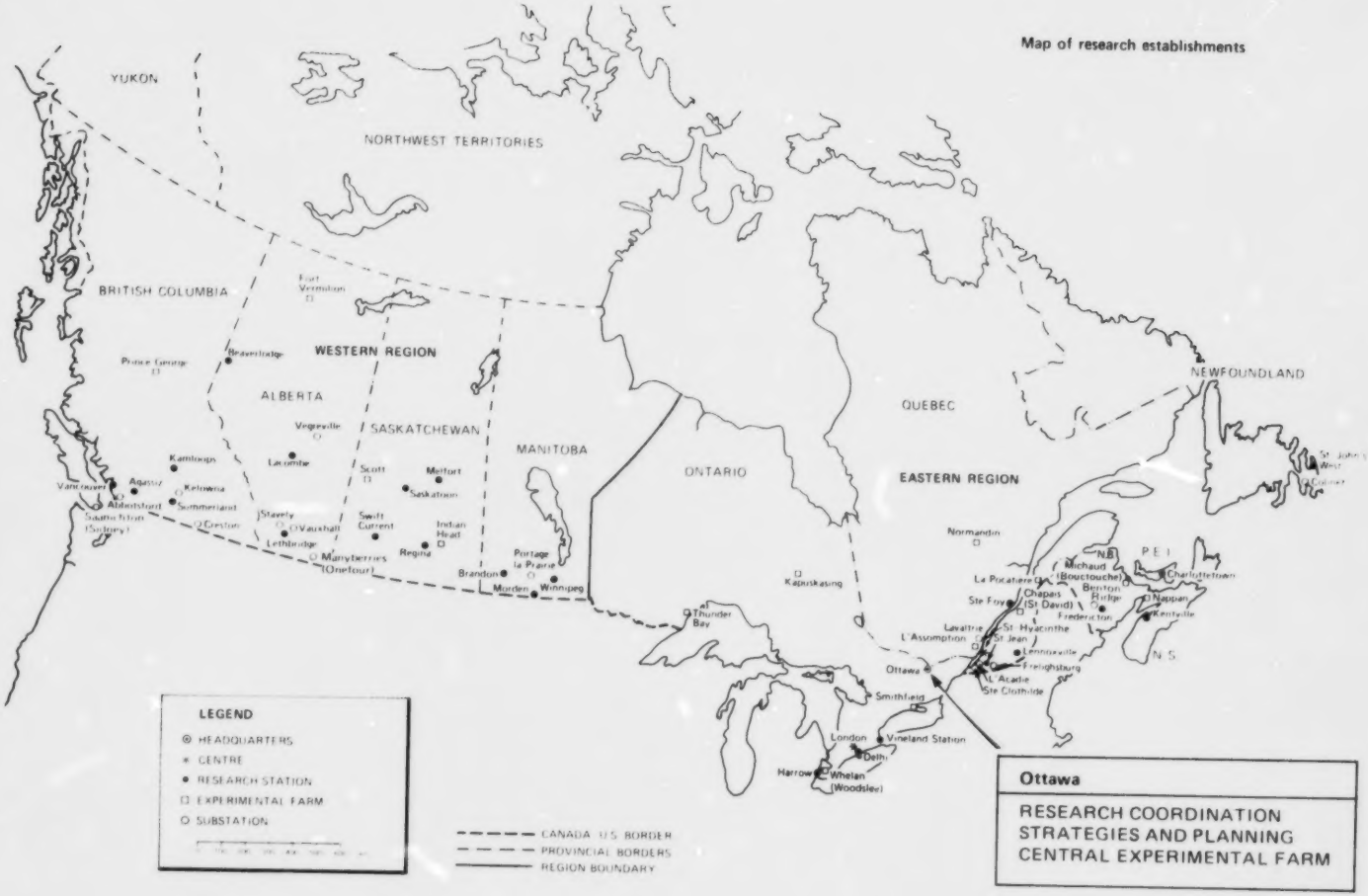
En 1988, la Direction générale de la recherche disposait d'un budget de 224 millions de dollars et d'un effectif de 3 480 membres dont 939 chercheurs.

La Direction générale de la recherche procède, en permanence, à des échanges scientifiques et technologiques avec plusieurs pays. La Direction générale fournit l'information et le personnel scientifique et technique nécessaire aux projets d'aide au développement parrainés par l'Agence canadienne de développement international (ACDI).

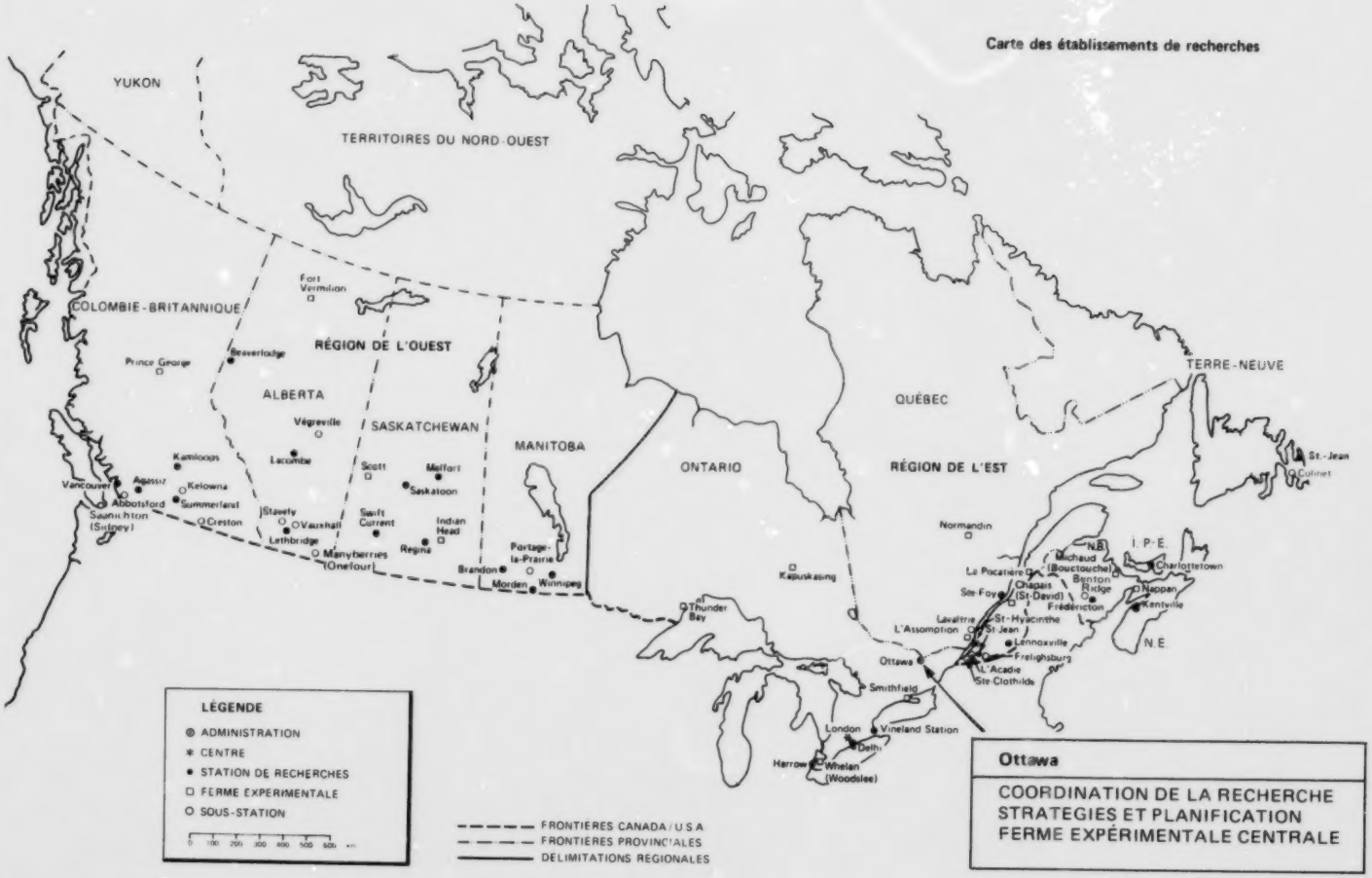
Le présent rapport souligne les efforts constants consacrés par le personnel de la Direction générale de la recherche à la réalisation d'un programme de recherche vaste et efficace qui profite à tous les segments du secteur agro-alimentaire.

A.O. Olson
Sous-ministre adjoint à la Recherche

Map of research establishments



Carte des établissements de recherches



A.O. Olson

C.B. Willis

D.F. Kirkland

J.C. St-Pierre

Y. Martel

D.G. Dorrell

C. Scott

G. Carpentier

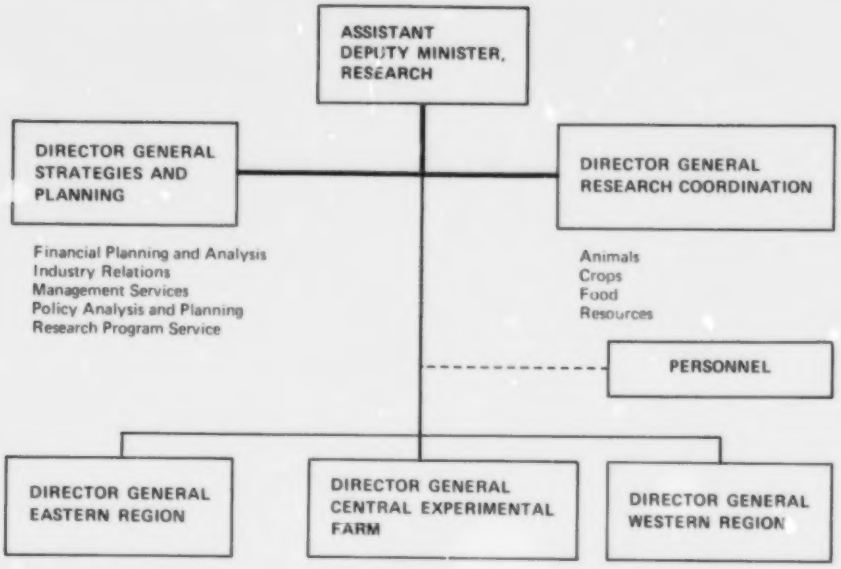
Headquarters
Administration centrale

BRANCH EXECUTIVE
HAUTE DIRECTION

Assistant Deputy Minister, Research *Sous-ministre adjoint à la Recherche*	A.O. Olson, B.Sc., Ph.D.
Directors General *Directeurs généraux*	
Research Coordination, acting *Coordination de la recherche, intérimaire*	C.B. Willis, B.Sc. (Agr.), Ph.D., F.A.I.C.
Strategies and Planning *Stratégies et planification*	D.F. Kirkland
Central Experimental Farm *Ferme expérimentale centrale*	J.C. St-Pierre, B.Sc. (Agr.), M.Sc., Ph.D.
Eastern Region *Région de l'Est*	Y. Martel, B.A., B.Sc.(Agr.), Ph.D.
Western Region *Région de l'Ouest*	D.G. Dorrell, B.S.A., M.Sc., Ph.D.
Special Adviser *Conseiller spécial*	C. Scott, B.A., D.P.A.
Branch Personnel Management, acting *Gestion du personnel de la Direction générale, intérimaire*	G. Carpentier,[1] B.A.
Departures *Départs*	
J.J. Cartier, B.A., B.Sc., Ph.D. Retired May 1988 *Retraité en mai 1988*	Director General, Eastern Region *Directeur général, Région de l'Est*
I.A. de la Roche, B.Sc., M.S., Ph.D. Resigned September 1988 *Démissionné en septembre 1988*	Director General, Priorities and Strategies *Directeur général, Priorités et stratégies*
J.R. Lessard, B.A., B.Sc., M.S., Ph.D. Retired December 1988 *Retraité en décembre 1988*	Executive Assistant *Adjoint exécutif*
W.L. Pelton, B.S.A., M.S.A., Ph.D. Transferred September 1988 *Muté en septembre 1988*	Director General, Western Region *Directeur général, Région de l'Ouest*

[1] **Personnel Administration Branch** *Direction générale de l'administration du personnel.*

ORGANIZATION OF THE RESEARCH BRANCH



Research Stations

St. John's West, Nfld.
Colinet, Nfld.
Charlottetown, P.E.I.
Kentville, N.S.
Nappan, N.S.
Fredericton, N.B.
Benton Ridge, N.B.
Michaud (Bouctouche), N.B.
Lennoxville, Que.
Sainte-Foy, Que.
La Pocatière, Que.
Normandin, Que.
Chapais (Saint-David), Que.
Saint-Jean, Que.
Frelighsburg, Que.
L'Acadie, Que.
L'Assomption, Que.
Lavaltrie, Que.
Sainte-Clothilde, Que.
Delhi, Ont.
Harrow, Ont.
Whelan (Woodslee), Ont.
Vineland Station, Ont.
Smithfield, Ont.

Experimental Farm

Kapuskasing, Ont.
Thunder Bay, Ont.

Research Centres

Food, Sainte-Hyacinthe, Que.
London, Ont.

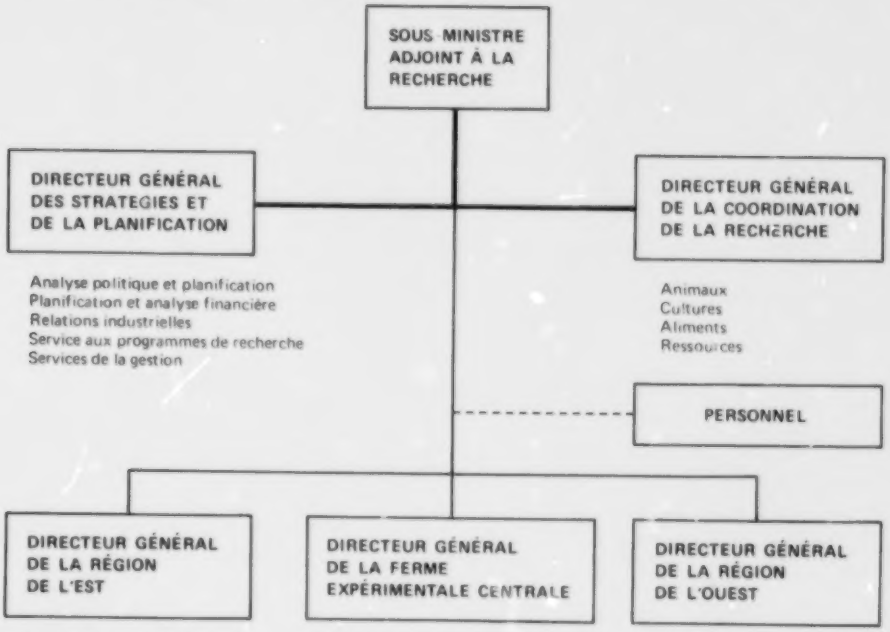
Research Centres

Animal
Biosystematics
Engineering and Statistical
Food
Land Resource
Plant

Research Stations

Brandon, Man.
Morden, Man.
Portage la Prairie, Man.
Winnipeg, Man.
Melfort, Sask.
Regina, Sask.
Indian Head, Sask.
Saskatoon, Sask.
Scott, Sask.
Swift Current, Sask.
Beaverlodge, Alta.
Fort Vermilion, Alta.
Lacombe, Alta.
Vegreville, Alta.
Lethbridge, Alta.
Manyberries (Onefour), Alta.
Stavely, Alta.
Vauxhall, Alta.
Agassiz, B.C.
Abbotsford, B.C.
Kamloops, B.C.
Prince George, B.C.
Summerland, B.C.
Creston, B.C.
Kelowna, B.C.
Vancouver, B.C.

ORGANISATION DE LA DIRECTION GÉNÉRALE DE LA RECHERCHE



Stations de recherches

Saint-Jean (T.-N.)
  Colinet (T.-N.)
Charlottetown (Î.-P.-É.)
Kentville (N.-É.)
  Nappan (N.-É.)
Frédéricton (N.-B.)
  Benton Ridge (N.-B.)
  Michaud (Bouctouche)(N.-B.)
Lennoxville (Québec)
Sainte-Foy (Québec)
  La Pocatière (Québec)
  Normandin (Québec)
  Chapais (Saint-David)(Québec)
Saint-Jean (Québec)
  Frelighsburg (Québec)
  L'Acadie (Québec)
  L'Assomption (Québec)
  Lavaltrie (Québec)
  Sainte-Clothilde (Québec)
Delhi (Ont.)
Harrow (Ont.)
  Whelan (Woodslee)(Ont.)
Vineland Station (Ont.)
  Smithfield (Ont.)

Ferme expérimentale

Kapuskasing (Ont.)
  Thunder Bay (Ont.)

Centres de recherches

Aliments
  (Saint-Hyacinthe)(Québec)
London (Ont.)

Centres de recherches

Aliments
Biosystématiques
Phytotechniques
Techniques et statistique
Terres
Zootechniques

Stations de recherches

Brandon (Man.)
Morden (Man.)
  Portage-la-Prairie (Man.)
Winnipeg (Man.)
Melfort (Sask.)
Regina (Sask.)
  Indian Head (Sask.)
Saskatoon (Sask.)
  Scott (Sask.)
Swift Current (Sask.)
Beaverlodge (Alb.)
  Fort Vermilion (Alb.)
Lacombe (Alb.)
  Végreville (Alb.)
Lethbridge (Alb.)
  Manyberries (Onefour)(Alb.)
  Stavely (Alb.)
  Vauxhall (Alb.)
Agassiz (C.-B.)
  Abbotsford (C.-B.)
Kamloops (C.-B.)
  Prince George (C.-B.)
Summerland (C.-B.)
  Creston (C.-B.)
  Kelowna (C.-B.)
Vancouver (C.-B.)

Headquarters

PROGRAM STRUCTURE OF THE RESEARCH BRANCH

Departmental objective

Agriculture Canada's objective is to promote the growth, stability, and competitiveness of the agri-food sector, by making available policies, programs, and services that are most appropriately provided by the federal government, so that the sector makes its maximum contribution to the economy.

Branch objective

The Research Branch's objective for the scientific research and development planning element is to maintain and improve the productivity of the agri-food sector through developing and transferring new knowledge and technology.

Objectives for branch planning sub-elements and sub-sub-elements

Management and administration. To provide the managerial, financial, personnel, and administrative services required for efficient management of the Research Branch.

1. Planning and program management
   To provide branch planning and program coordination in support of senior branch management.

2. Administrative services
   To provide support for branch management in financial, personnel, and any other administrative areas necessary for the efficient functioning of the branch.

Resource and research. To produce scientific and technical information and to develop technology that will assist the agri-food sector in managing and conserving the natural resources necessary for agricultural production, while increasing the level and efficiency of production, and that will assist other researchers in developing applied technology.

1. Land
   To provide accurate information about the quantity, quality, and location of Canada's land resource and to better understand the properties of soils, which affect agricultural productivity.

2. Water and climate
   To improve water management on Canadian soils in order to increase productivity and to monitor and preserve environmental quality within the constraints imposed by Canada's northern climate.

3. Energy and engineering
   To develop and adapt engineering technology that will optimize energy utilization and efficiency of production, storage, processing, and distribution of agricultural products.

4. Biological resources
   To provide accurate information about the quantity, quality, and location of Canada's biological resources (including vascular plants, insects, arachnids, nematodes, fungi, and bacteria) and to provide identification services that can be used as required to ensure agricultural productivity.

5. Biotechnology
   To assess, develop, and utilize technology in support of basic and applied agricultural research.

6. Protection
   To provide new, general, and basic research information on the protection of animals and crops from diseases, insects, and weeds.

7. Scientific support services
   To provide for all scientific researchers the statistical, graphic arts, publishing, and other general support services necessary to maintain the quality and quantity of output of research findings.

Animal research. To produce scientific and technical information and develop new technology that will assist the primary producer in increasing the quality and efficiency of the production of animals.

1. Beef
   To improve the efficiency of beef production and the quality of beef products in support of regional, domestic, and export market development.

2. Dairy
   To improve the efficiency of milk production for domestic and export market development.

3. Swine
   To improve the efficiency of pork production and the quality of pork and pork products in support of domestic and export market development.

4. Poultry
   To improve the efficiency of production of eggs and poultry meat and the quality of poultry products in support of domestic and export market development.

5. Other animals
   To increase the efficiency of production and quality of products from sheep, honey bees, fur bearers, and any other animals deemed to be of agricultural importance in support of domestic and export market development.

Crop research. To produce scientific and technical information and develop new technology that will assist the primary producer in increasing the quality and efficiency of the production of crops.

1. Cereals
   To increase the production efficiency, quality, and protection of cereal crops for domestic and export markets.

2. Oilseeds
   To increase the efficiency of production adaptability and the quality of oilseed crops and their products for domestic and export markets.

3. Forages
   To increase the efficiency of production adaptability and the quality of domestic forage crops in support of livestock production.

4. Field crops
   To increase the production efficiency, quality, and protection of field crops such as tobacco, field peas, buckwheat, and field beans.

5. Vegetables
   To increase the efficiency of production, protection, adaptability, and quality of vegetables for the domestic market, and of potatoes and seed potatoes for export.

6. Tree fruits and berries
   To increase the efficiency of production, protection, adaptability, and quality of tree fruits and berries for domestic and export markets.

7. Ornamentals
   To develop, test, and release high-quality ornamental plants that are adapted to Canada's climatic regions.

Food research. To produce scientific and technical information and develop technology that will assist the agri-food processing sector in increasing the efficiency and effectiveness of crop and animal commodity processing, while ensuring the safety and nutritional value of food.

1. Food processing, equipment, and products
   To develop new food-processing technology, to improve the efficiency and effectiveness of food-processing systems, and to develop and characterize new uses of products and ingredients from agricultural crops and animal products.

2. Food safety and nutrition
   To increase consumer safety from antinutritional and toxic constituents in food and to monitor and improve the nutritive value of agricultural products.

3. Storage
   To develop and apply processes and handling procedures for maintaining the quality of foods after crop harvest.

STRUCTURE DU PROGRAMME DE LA DIRECTION GÉNÉRALE DE LA RECHERCHE

Objectif du Ministère

L'objectif d'Agriculture Canada est de promouvoir la croissance, la stabilité et la compétitivité du secteur agro-alimentaire au moyen de politiques, de programmes et de services fournis par le gouvernement fédéral, de façon à assurer une contribution optimale de ce secteur à l'économie.

Objectifs de la Direction générale

L'élément planification de la recherche scientifique et du développement de la Direction générale de la recherche a pour objectif d'améliorer la productivité du secteur agro-alimentaire en mettant au point de nouvelles technologies et en diffusant les connaissances.

Objectifs des sous-divisions et des sous-sous-divisions de la planification

Gestion et administration. Fournir les services nécessaires dans les domaines de la gestion, des finances, du personnel et de l'administration afin d'assurer une gestion efficace de la Direction générale.

1. Gestion et planification des programmes
   Assurer la planification et la coordination des programmes de la Direction générale afin d'appuyer la Haute Direction.

2. Services administratifs
   Fournir un soutien à la Haute Direction dans les domaines des finances, du personnel et dans tout autre domaine administratif pour assurer le bon fonctionnement de la Direction générale.

Recherche sur les ressources. Mettre à la disposition du secteur agro-alimentaire des informations scientifiques et techniques et développer des technologies qui l'aideront à gérer et à conserver les ressources naturelles nécessaires à la production agricole tout en augmentant leur utilisation efficace : ces mêmes ressources doivent aider les chercheurs à mettre au point des technologies appliquées.

1. Terres
   Fournir des informations précises sur la quantité, la qualité et l'emplacement des ressources en terres du Canada et parvenir à une meilleure connaissance des propriétés des sols, qui influent sur la productivité agricole.

2. Eau et climat
   Améliorer la gestion des eaux sur les sols du Canada afin d'accroître la productivité et de contrôler et conserver la qualité de l'environnement, en tenant compte des contraintes imposées par le climat boréal du Canada.

3. Énergie et génie
   Développer et adapter une technologie pour optimiser le rendement énergétique et l'efficacité de la production, du stockage, de la transformation et de la distribution des produits agricoles.

4. Ressources biologiques
   Fournir des informations précises sur la quantité, la qualité et l'emplacement des ressources biologiques du Canada (notamment les plantes vasculaires, insectes, arachnides, nématodes, champignons et bactéries) et offrir des services d'identification sur demande pour assurer la productivité agricole.

5. Biotechnologie
   Évaluer, développer et appliquer une technologie à l'appui de la recherche agricole fondamentale et appliquée.

6. Protection
   Fournir les résultats généraux et fondamentaux sur la recherche dans le domaine de la protection des animaux et des récoltes contre les maladies, les insectes et les mauvaises herbes.

7. Services de soutien scientifique
   Fournir à tous les chercheurs des statistiques, des publications et tout autre service d'aide générale nécessaire au maintien de la qualité de la recherche et à l'accroissement de la productivité des opérations.

Recherche sur les animaux. Produire l'information scientifique et technique et élaborer une nouvelle technologie afin d'aider le producteur primaire à augmenter la qualité et l'efficacité de la production animale.

1. Bovins de boucherie
   Accroître l'efficacité de la production bovine et améliorer la qualité des produits pour les marchés régional, national et d'exportation.

2. Bovins laitiers
   Accroître l'efficacité de la production laitière pour les marchés national et d'exportation.

3. Porcs
   Accroître l'efficacité de la production porcine et améliorer la qualité des produits pour les marchés national et d'exportation.

4. Volaille
   Accroître l'efficacité de la production des oeufs et de la volaille et améliorer la qualité des produits avicoles pour les marchés national et d'exportation.

5. Autres animaux
   Accroître l'efficacité de la production ovine, apicole, d'animaux à fourrure et de tous les autres animaux jugés importants pour l'agriculture, pour les marchés national et d'exportation.

Recherche sur les cultures. Produire de l'information scientifique et technique et élaborer une nouvelle technologie afin d'aider le producteur primaire à augmenter la qualité et l'efficacité de la production animale.

1. Céréales
   Accroître l'efficacité, la qualité et la protection des cultures céréalières pour les marchés national et d'exportation.

2. Oléagineux
   Accroître l'adaptabilité sur le plan productif et la qualité des oléagineux et de leurs produits pour les marchés national et d'exportation.

3. Fourrages
   Accroître l'adaptabilité sur le plan productif et la qualité des cultures fourragères sur le plan national afin d'aider à la production du bétail.

4. Grandes cultures
   Accroître l'efficacité de la production, la qualité et la protection des grandes cultures comme le tabac, le pois sec, le sarrasin et le haricot sec.

5. Légumes
   Accroître l'efficacité de la production, la protection, l'adaptabilité et la qualité des légumes pour le marché national, et des pommes de terre et des pommes de terre de semence pour l'exportation.

6. Fruits de verger et petits fruits
   Accroître l'efficacité de la production, la protection, l'adaptabilité et la qualité des arbres fruitiers et des baies afin d'augmenter les marchés national et d'exportation.

7. Plantes ornementales
   Développer, tester et distribuer des plantes d'ornement de grande qualité qui soient adaptées aux différentes régions climatiques du Canada.

Recherches sur les aliments. Fournir l'information scientifique et technique et élaborer la technologie à l'appui du secteur de la transformation agro-alimentaire afin d'accroître l'efficacité et la rentabilité de la transformation des produits animaux et végétaux tout en assurant la salubrité et la valeur nutritive des aliments produits.

1. Transformation des aliments, équipements et produits
   Élaborer de nouvelles techniques de transformation des produits alimentaires, accroître l'efficacité et la rentabilité des systèmes de transformation et élaborer et caractériser de nouvelles façons d'utiliser des produits et ingrédients provenant des cultures et des animaux.

2. Innocuité des aliments et nutrition
   Accroître la protection des consommateurs contre les constituants alimentaires toxiques et néfastes sur le plan nutritif et d'assurer et rehausser la valeur nutritive des produits agricoles.

3. Entreposage
   Développer et mettre en pratique des façons de procéder pour maintenir la haute qualité des aliments après la moisson.

Research Coordination Directorate

Direction de la coordination de la recherche

C.B. Willis

L.M. Benzing-Purdie

R. Bouchard

R.G. Fulcher

E. Larmond

G.A. Neish

W.J. Saidak

Research Coordination
Ottawa, Ontario

PROFESSIONAL STAFF

C.B. Willis, B.Sc.(Agr.), Ph.D., F.A.I.C.	Acting Director General

Research Coordinators

L.M. Benzing-Purdie, B.Sc., M.Sc., Ph.D	Natural resources, acting
R. Bouchard, B.A., B.S.A., M.Sc., Ph.D.	Animals
R.G. Fulcher, B.A., M.Sc., Ph.D.	Grains and oilseeds, acting
E. Larmond, B.Sc.	Food
G.A. Neish, B.Sc., Ph.D.	Multidisciplinary
W.J. Saidak, B.S.A., M.S., Ph.D., F.W.S.S.A.	Grains and oilseeds

Special Advisers

J.W. Martens, B.Sc., Ph.D.	Crop protection
M. Nazarowec-White, B.Sc., M.Sc.	Food
K.A. Winter, B.Sc.(Agr.), M.Sc., Ph.D.	Animals

Departures

I.A. de la Roche, B.Sc., M.S., Ph.D.	Director General
B.B. Chubey, B.S.A., M.Sc., Ph.D.	Special Adviser, Horticulture and special crops
R. Hironaka, B.Sc., M.Sc., Ph.D.	Special Adviser, Animal production
P.W. Perrin, B.Sc., Ph.D.	Special Adviser, Food

INTRODUCTION

Research coordinators and special advisers provide a national perspective in advising on the direction of research programs across the Research Branch. They report to the director general of the Research Coordination Directorate to provide scientific expertise and advice on program issues to the Assistant Deputy Minister, the Deputy Minister, and the Minister. The coordinators provide scientific expertise to international delegations, play leadership roles in Canada committees and expert committees of the Canadian Agricultural Services Coordinating Committee (CASCC), conduct research station and research program reviews, act as liaison between the Research Branch and its clients, and provide the perspective of the scientist–manager to program rationalization, human resource planning, scientist appraisals, branch restructuring, and resource allocation. Special advisers are seconded from establishments to perform duties similar to those of the coordinators.

During 1988, the Research Coordination Directorate was heavily involved in assisting with the fine-tuning of Research Branch activities to conform with the *Research Branch proposal for action*, Part 5 of *Canadian agricultural research and technology transfer: Planning for the future*. These activities included major reviews such as the eastern cereals, western wheat, Saint-Hyacinthe Food Research Centre, potato breeding, and tomato breeding, as well as other programs and research stations. The group also made important contributions to Research Branch and departmental responses to issues of current importance such as hormones in animal production, climatic change, biotechnology, and sustainable agriculture.

Further information can be obtained from the Director General, Research Coordination Directorate, Research Branch, Agriculture Canada, Ottawa, Ont. K1A 0C5; Tel. (613) 995-7084.

C.B. Willis
Acting Director General

CROPS

Input to policy, planning, and program development

The Research Coordination Directorate provided leadership or participated in the potato breeding review, the tomato breeding review, the eastern cereal review, the eastern forage crops review, the western wheat review, the grain quality review, and the Sainte-Foy, Regina, and Winnipeg research station reviews. In cooperation with the directors general, reviews have been completed of potato breeding, tomato breeding, eastern cereals, and eastern forage crops. The reports including recommendations have been approved by Branch Management Committee. The reviews included consultation with all sectors of the industries, with branch and university personnel, and with provincial government officials. Recommendations include program guidelines for improving communication among the major breeding programs in Canada and will result in improved efficiencies in these breeding programs. The western wheat review involved all members of the western wheat industry, including producers, the Canadian Wheat Board, specialists from provincial governments and universities and breeders and pathologists from Agriculture Canada. Review recommendations have been formulated and should lead to improved efficiencies in western wheat breeding and research activities. The grain quality review, which addressed activities and requirements for testing grain quality, was conducted in consultation with industry, university, and federal personnel involved in cultivar development. Additional meetings with staff at other research stations in western Canada contributed to information exchange and identification of issues of interest to research scientists and managers involved in programs of crop protection research.

The directorate provided support and participated in the Plant-Virus Biotechnology Workshop held at the Vancouver Research Station. This workshop resulted in a timely, comprehensive review of plant virology research in federal government and university research laboratories, with a focus on the identification of current and future needs, opportunities, and constraints affecting plant

virology research and technology transfer in Canada.

In collaboration with scientists from the Eastern Region the reports of the workshops on integrated pest management (IPM) in apple orchards and on IPM for potatoes were completed, published, and distributed to participants and branch managers.

Assistance with the initiation of the review of roles and responsibilities for research on biological resources identified in the *Research Branch proposal for action*, Part 5 of *Canadian agricultural research and technology transfer: Planning for the future* was provided to the Central Experimental Farm.

Interbranch and interdepartmental activities

The Research Branch played a key role in the development of a departmental response to the theme of sustainable development as it relates to the agricultural sector. The Research Coordination Directorate was responsible for initiating interbranch consultations in sustainable agriculture in 1988 and collaborated with the Policy Branch in the organization of interbranch meetings on this subject. Related activities included attendance at relevant conferences in Canada and the United States, a visit to the Rodale Research Center, and discussions with farmers, researchers, and extension specialists concerned with agricultural production systems that minimize dependence on purchased inputs.

The directorate continued to provide administrative support and a secretariat function for the Task Force on the Status of Culture Collections in Canada whose report, *Culture collections in Canada*, was presented to the Minister of State for Science and Technology in October 1988. The directorate also participated in the activities of the Ministry of State for Science and Technology's biotechnology coordinating group, which supports the federal Interdepartmental Committee on Biotechnology.

In cooperation with the Food Production and Inspection Branch a presentation concerned with the regulation of pesticides and with alternatives to synthetic chemical pesticides was made to the House of Commons Standing Committee on Environment and Forestry. The Research Branch also collaborated with the Food Production and Inspection Branch in cofunding an independent consultant review of the Minor Use of Pesticides Program; directorate staff participated in this review.

The directorate provided a scientific secretary to the Cell Biology and Genetics Grant Selection Committee of the Natural Sciences and Engineering Research Council (NSERC). Also, by providing a rapporteur for one of the workshops, the directorate represented Agriculture Canada at the Prime Minister's National Conference on Technology and Innovation held in Toronto, 13–15 January 1988.

The directorate continued to work closely with the regions in the implementation of the national agricultural biotechnology initiative.

Extramural activities

In cooperation with External Affairs, the directorate provided the departmental and Canadian liaison with CAB International (CABI) and participated in the activities of the CABI working party on future financial arrangements and governing structure, through correspondence and by attendance at the working party meetings held in London, England, 7–9 November 1988.

Support was provided to the Canadian Agricultural Research Council (CARC) through chairmanship of the CARC standing committee on biotechnology in agriculture and food, through participation in the CARC workshop on the regulation of agricultural products of biotechnology, and through contributions to meetings of council.

ANIMALS

Input to policy, planning, and program development

The Research Coordination Directorate participated in the continuing rationalization of the sheep and dairy research programs based on previous recommendations and the need to cope with reduced resources. Dairy research is being directed toward more basic studies while consolidation of the sheep research at two establishments and adjustments to animal numbers has continued. These programs focus on the long-term marketability of animal products to keep Canadian producers competitive in international trade. The dairy program at Fredericton, the genetics–environment interaction programs at Lethbridge and Brandon, and the livestock pest program at Lethbridge were reviewed. Further definition

of the roles of these establishments was developed. The involvement of nonfederal research partners is being strengthened in dairy, beef, and poultry research.

Interbranch activities

The directorate was involved in developing several new initiatives in cooperation with the Agriculture Development Branch and the Food Production and Inspection Branch in the area of product marketing. Assistance was provided to the Audit and Evaluation Branch in assessing the role of regional agricultural development and in the departmental activity toward developing a position on sustainable agriculture. Leadership was provided in developing guidelines for animal welfare and in drafting and preparing a code of practice for the care and handling of dairy cattle. The total departmental effort in animal welfare was evaluated in cooperation with the Food Production and Inspection Branch.

Extramural activities

The directorate cooperated and consulted with producer–commodity groups including the Dairy Farmers of Canada, Canadian Cattlemen's Association, Canada Pork Council, Canadian Association of Animal Breeders, Canada Sheep Council, the Canadian Feed Industry Association, and the Canadian Animal Health Institute. Private ownership of research herds was discussed.

FOOD

Input to policy, planning, and program development

A review of the Research Branch's food research program was initiated to define Agriculture Canada's role and responsibilities. Consultations with other publicly funded agencies were held to ensure complementarity.

The program and services of the Saint-Hyacinthe Food Research Centre were reviewed. Industry consultation was a key component of the review. The report was accepted by the Branch Management Committee, and the recommendations are being implemented.

Appropriate goals for the food research program were developed and integrated into the *Branch Head Plan*.

Interbranch activities

A management council committee to examine the evolving role of Agriculture Canada vis-à-vis the public was chaired by directorate personnel. This interbranch committee recommended that the department learn more about consumer concerns regarding food safety and inform the public about the existing system for food safety.

Support to CASCC

In addition to the normal assessment of research recommendations, the secretariat function was provided to the Canada Committee on Food. An ad hoc committee of CARC on the role of red meat in the nutrition of Canadians was chaired by the research coordinator, food. The committee commissioned a report on the same subject and presented it to CARC.

Extramural activities

Directorate personnel participated on the steering committee for the evaluation of the federal contribution to the POS (protein oil and starch) Pilot Plant Corporation. The evaluation report was accepted by the department.

Research Branch representation on the board of directors and the technical planning committee on the POS Pilot Plant Corporation was provided by the directorate.

Assistance was given to the Canadian Meat Council in establishing a meat research information system which is compatible with the planned changes to the Inventory of Canadian Agricultural Research (ICAR).

Two meetings were held with representatives of federal, provincial, and university food research and development centres to discuss information exchange and technology transfer.

NATURAL RESOURCES AND ENVIRONMENT

Input to policy, planning, and program development

A proposal for action in the natural resource research area was developed in response to two elements of the national agricultural strategy, i.e., protection of natural resources, and environmental concerns. Research into soil degradation and conservation was given high priority as was research pertaining to fertilizer

use and pesticide movement and degradation in the environment. The need was identified for crop production systems adapted to diverse soil and climatic conditions and for improved systems and practices of drainage and irrigation management.

Strong links were maintained with the national soil conservation program. The Research Coordination Directorate provided background information on branch projects in soil conservation and commented on the proposed soil and water accords, soil conservation program agreements, and work plans.

In response to requests, the directorate identified soil research priorities in biotechnology for the Ministry of State for Science and Technology. Specific targeted research areas pertaining to the preservation of the quality of the environment were identified for NSERC.

Environmental issues in general received a great deal of attention. The directorate provided briefing material for the tetrapartite meeting in Paris, France. A background paper on environmental policy issues and regulations was prepared for a departmental planning meeting. This paper included short-, medium-, and long-term effects on agriculture of policies and regulations and of problems such as deterioration in water quality, soil degradation, and possible climatic change. Furthermore, a document describing all linkages between the Research Branch and Environment Canada was produced.

In the field of climate, the directorate became active in the Canadian Institute for Research in Atmospheric Chemistry to strengthen coordination of Research Branch efforts with other government departments, universities, and the private sector. In addition, present and planned research projects on atmospheric change and its effects were identified as a first step in the development of a Research Branch position on the topic. A paper entitled *Climate change and agriculture* was prepared as background material for discussion at the departmental level.

A number of unsolicited proposals were reviewed in support of the Industry Relations Office.

Interbranch and interdepartmental activities

The directorate provided support to the Minister and the Deputy Minister in various areas pertaining to the environment, e.g., sustainable development, climate change, and soil and water activities.

The directorate, which acted as the link between the department and other agencies involved in atmospheric change, had membership in a number of committees including: The Federal Committee on Atmospheric Change and Impacts; The Canadian Climate Program; and The Long Range Transport of Air Pollutants—Research Monitoring and Coordinating Committee. As contact point for this issue, the directorate was a major player in the preparation of an interdepartmental document on climatic change and also contributed to the Intelligence Advisory Committee (Privy Council Office) paper on *Implication of an enhanced greenhouse effect for Canada.*

The Research Branch and the department were represented on various interjurisdictional forums, including the Interdepartmental Committee on Land and Le Comité de Programme 3-C («Aide à l'innovation technologique en conservation du sol agricole et de l'eau» dans le cadre de l'Entente Canada/Québec sur le développement agro-alimentaire).

The directorate provided reviews and comments for several memoranda to cabinet from the departments of Energy, Mines and Resources and Environment.

Support to CASCC

The directorate assessed research needs under CASCC activities and reviewed its recommendations on research and development and other matters.

Extramural activities

An invited paper entitled *Climate change and agriculture* was given at the annual meeting of the Canada Committee on Land Use.

In view of the consequences of possible climatic change for the agricultural sector, Research Branch supported the World Conference on the Changing Atmosphere: Implications for Global Security and organized the workshop on food security. Directorate staff also attended the Second North American Conference on Preparing for Climate Change held in Washington.

The directorate participated in the Sixth Annual Western Provinces Conference on Rationalization of Soil and Water Management—Policies and Institutions with Impact on Soil and Water in Manitoba and in the Soil Conservation Conference: Working in Harmony in Quebec.

Strategies and Planning Directorate

Direction des stratégies et de la planification

D.F. Kirkland

J.E. Renaud

J.-M. Deschênes

I.M. Wood

A.M. Cooper

Y. Bélanger

Director General *Directeur général* D.F. Kirkland

Division Directors *Directeurs des divisions*

Financial Planning and Analysis *Planification et analyse financière*	J.E. Renaud
Industry Relations, acting *Relations industrielles, intérimaire*	J.-M. Deschênes, B.Sc., M.Sc., Ph.D.
Management Services *Services de la gestion*	I.M. Wood
Policy Analysis and Planning, acting *Analyse politique et planification, intérimaire*	A.M. Cooper, B.Sc.
Research Program Service *Service aux programmes de recherche*	Y. Bélanger, B.Sc.

Financial Planning and Analysis
Ottawa, Ontario

PROFESSIONAL STAFF

J.E. Renaud, C.D.	Director
K. Archer, C.M.A.	Chief, Financial Planning and Analysis
A.L. Dignard	Adviser, Eastern Region
G. McKane, B.A., C.M.A.	Adviser, Western Region
J.B. Moran	Adviser, Central Experimental Farm

INTRODUCTION

The Financial Planning and Analysis Division is a service organization. It has five major functions: to provide all the financial inputs required by central agencies; to direct the budgeting of person-years and dollars; to foster the economic, effective, and efficient use of those resources; to provide financial guidance and advice to all levels of management from the Assistant Deputy Minister to the staffs of responsibility centres; and to participate in policy development and implementation. These functions are carried out by a core financial planning and analysis group and teams of financial advisers assigned to the three regional directors general. The advisers are members of the regional management committees, and the director is a member of the Branch Management Committee.

Enquiries can be directed to the Director, Financial Planning and Analysis Division, Research Branch, Agriculture Canada, Ottawa, Ont. K1A 0C5; Tel. (613) 995-7084.

J.E. Renaud
Director

ACHIEVEMENTS

The division prepared the financial inputs for the Research Branch's portions of departmental reports to the Treasury Board and other departments, e.g., the *Multi-Year Operational Plan* (MYOP), *Main Estimates*, *Supplementary Estimates*, *Science Addendum*, and other submissions and reports.

Guidelines and assistance were provided to managers at all levels for the preparation and validation of annual resource plans and costed work plans.

Budgets totaling 3484 person-years and $245 000 000 were monitored and controlled throughout the year. This involved the development of alternatives for decisions in resource allocations, reallocations, and reductions and subsequent adjustments to budgets and allotments, as well as the negotiation of cash transfers among regions and from other branches as needed.

A proactive role was maintained in advising managers on situation analysis, problem avoidance, and program support, including interpreting and implementing corporate and central agency policies.

Reports, schedules, briefings, and correspondence for the Minister, the Deputy Minister, the Assistant Deputy Minister, and the directors general were prepared on financial matters. Various cyclical reports, such as variance reports and cash forecasts, were also prepared.

Industry Relations, Ottawa, Ontario

PROFESSIONAL STAFF

J.-M. Deschênes, B.Sc., M.Sc., Ph.D.	Acting Director
E.K. Endemann,[1] B.A.	International programs
W.L. Fettes[1]	International liaison
K.W. Lievers, B.Sc., M.Sc.	Industry relations
J.S. McKenzie, B.S.A., M.Sc., Ph.D.	Industry relations

Departure

P.W. Voisey, F.I., Mech.E. End of assignment, November 1988	Acting Director

[1] Transferred from Policy and Client Relations, November 1988.

INTRODUCTION

The Industry Relations Office (IRO) was established in August 1987 to develop enabling mechanisms to facilitate the transfer and commercialization of Research Branch's technologies and to strengthen research partnerships with the private sector and other research partners. In November 1988, the International Research and Development Office joined IRO to facilitate linkages between domestic and international activities.

Major achievements of the IRO since its establishment include the development of a policy for the release of Agriculture Canada (AC) corn inbreds and hybrids to industry worldwide; the signing of an agreement with a French organization to maintain, protect, and promote AC corn inbred lines in Europe; the establishment of a specified purpose account to conduct collaborative research; and the approval by the Minister for the worldwide licensing and collection of royalties for all plant varieties developed by Agriculture Canada.

More complete information may be obtained by writing to the Director, Industry Relations Office, Research Branch, Agriculture Canada, Ottawa, Ont. K1A 0C5; Tel. (613) 995-7084.

J.-M. Deschênes
Acting Director

INDUSTRY RELATIONS

During 1988, the major achievements were related to release of corn inbreds and hybrids, collection of royalties, and collaborative research agreements. Specifically, a contract has been signed with a French organization for the protection, maintenance, promotion, and distribution of inbred lines in the European Economic Community (EEC) and Switzerland. Significant progress has been made in negotiating rates for European royalties and in organizing the collection of royalties for AC corn inbred lines commercialized in the EEC and Switzerland.

Standard agreements for the release of AC corn inbreds for research purposes and for licensing hybrids have been developed. An inbred licensing agreement has been drafted for discussion with the industry. Sixteen corn hybrids and 24 inbred lines were released to industry and 11 sunflower inbreds and 1 hybrid were released from the Morden Research Station using the corn agreements as a model.

Guidelines for entering into agreements with external collaborators have been developed, reviewed by the Corporate Management Branch, approved by the Branch Management Committee, and distributed to research establishment managers.

The specified purpose account has been established and is now operational. Managers at research establishments can now accept collaborators' financial contributions toward a specific project and spend the funds on direct and incremental overhead costs.

The Minister of Agriculture has authorized the worldwide licensing and collection of royalties for all plant varieties developed by Agriculture Canada. In addition, SeCan Association has agreed to collect royalties from the sales of certified seed and for the right to reproduce breeder's seed from new seed crop varieties in 1989. Likewise, the Canadian Ornamental Plant Foundation has agreed to enter into an agreement to collect royalties on behalf of Agriculture Canada for ornamental species.

INTERNATIONAL RELATIONS

In 1988, the Research Branch continued its support to departmental objectives pertaining to international science and technology and official development assistance programs.

Bilateral and multilateral projects and relations were coordinated with some 55 countries and international agencies to enhance our domestic research capability and to ensure that Canadian government policies on agricultural science and techology were supported and encouraged internationally. All these activities were coordinated by the International Research and Development Office, which joined IRO in November 1988.

The branch was responsible for the management of 10 official development assistance (ODA) projects in six countries, funded by the

Canadian International Development Agency (CIDA), and seven ODA projects in six countries funded by the International Development Research Centre (IDRC). Branch scientists also provided scientific expertise for a wide range of other international activities for CIDA and IDRC. In 1988 about 100 foreign scientists visited branch establishments for training in techniques directly applicable to their country's agricultural development.

Scientific and technical assistance was provided by the branch in support of Canadian promotional activities, such as technical seminars and trade expositions aimed at expanding foreign markets for Canadian agricultural products.

Management Services, Ottawa, Ontario

PROFESSIONAL STAFF

I.M. Wood	Director
M. Craib	Contracts and agreements
G. Desmarais	Text reviser
F. Drury[1]	Systems
D.W. Friel	Head, Assets Management
J. Johanis	Administrative services
G.F. Morris[2]	Health and safety
A. Severn	Materiel management
M.B. Trudel[2]	Planning and systems
D. Violette	Real property

Departure

S.C. Cassidy On special assignment with Land Resource Research Centre from 12 September 1988	Planning and systems

[1] Seconded from Corporate Management Branch.
[2] Seconded from Land Resource Research Centre.

INTRODUCTION

The Management Services Division provides administrative services and advice to branch management both at the headquarters level and at the responsibility centre level. These responsibilities are fulfilled through a group of officers and support staff with expertise in the areas of contracts and agreements, general administration, assets management, text revision, and special projects. Some of the senior members of the staff act as liaison officers with the regional directors general and participate as members of regional and departmental management committees. The division also provides support to the branch headquarters staff in such areas as word processing, materiel management, and accounts processing.

Enquiries can be directed to the Director, Management Services Division, Research Branch, Agriculture Canada, Ottawa, Ont. K1A 0C5; Tel. (613) 995-7084.

I.M. Wood
Director

ACHIEVEMENTS

The Management Services Division, in its 2nd year of operation, continued to promote communication with the responsibility centres in the Research Branch. This function was achieved through the normal day-to-day contact via telecommunications and, in addition, through regional administrative meetings held in Ottawa, London, Halifax, and Calgary. In the area of administration assistance, advice, clarification, and interpretation of policies and procedures were provided to all levels of management.

Throughout the year, the division performed its role of liaising with other branches of the department on behalf of establishments across the country concerning the various responsibilities associated with administration.

The division allocated resources to the promotion of the proper management of dangerous substances and to the initial stage of implementation of the Workplace Hazardous Materials Information System. A real property data base was developed and property management guidelines were issued for use by all branch managers.

Additional resources were allocated to aid the branch in the area of office automation. The first stage of the microcomputerized management information processing system was implemented. It is anticipated that most responsibility centres will adopt the system.

One officer was assigned to the Industry Relations Office to provide administrative support in the development of guidelines, policies, and procedures regarding collaborative projects with industry.

Some adjustments were made to the structure of the division to provide more effective administrative support to staff located at headquarters in Ottawa.

Policy Analysis and Planning
Ottawa, Ontario

PROFESSIONAL STAFF

A.M. Cooper, B.Sc.	Acting Director
G.W. Andrews, B.Sc.F., M.Sc.	Policy and planning
J. Dingwall, B.A., Ph.D.	Resources
J.P. Hayes, B.Sc., M.Sc.	Planning
G. Poushinsky, B.Sc., M.Sc.	Planning

Departures

D.F. Kirkland Transferred to Strategies and Planning Directorate as director general, 1 September 1988	Director
E.K. Endemann, B.A. Transferred to Industry Relations, 1 November 1988	International programs
W.L. Fettes Transferred to Industry Relations, 1 November 1988	Branch Liaison—international
M.K. John, B.Sc.(Agr.), M.Sc., Ph.D. Transferred to Land Resource Research Centre, 25 January 1988	Special Adviser, resources
J.A. Perrin, B.Sc. Retired October 1988	Operations processes

INTRODUCTION

During 1988 the Policy and Client Relations Division evolved into Policy Analysis and Planning, one of five divisions of the newly formed Strategies and Planning Directorate. Enquiries can be directed to the Director, Policy Analysis and Planning Division, Research Branch, Agriculture Canada, Ottawa, Ont. K1A 0C5; Tel. (613) 995-7084.

A.M. Cooper
Acting Director

POLICY

Response to government issues

The Policy Analysis and Planning Division undertakes activities in a variety of policy areas mostly related to science and technology. One major focus has been the active liaison with central agencies, e.g., Treasury Board and Ministry of State for Science and Technology, to provide input for the development and interpretation of broad policies and policy instruments related to federal science and technology. During 1988 the division was responsible for the preparation of the 1988 annual science and technology plan, as well as for the development of frameworks for cost recovery, intellectual property, and joint ventures.

Secondments

On behalf of the branch, the Strategies and Planning Directorate is responsible for the coordination of secondment programs both inside and outside the branch. During 1988 John Dingwall from Treasury Board joined the Policy Analysis and Planning Division to analyze resource issues, Greg Poushinsky was taken on to deal with amendments to the *Experimental Farm Stations Act*, and Jery Hayes was assigned to work on linking the strategic plan commitments to the operational planning process and to integrate with the study data base.

PLANNING

Strategic planning

The branch continues to make excellent progress in fulfilling the commitments of its new strategic directions. The *Research Branch proposal for action*, Part 5 of *Canadian agricultural research and technology transfer: Planning for the future*, was developed by the branch in March of 1988. This paper constituted the Research Branch plan for implementing its part of the overall research strategy. It was tabled with the ministers in July 1988 and was subsequently distributed to industry, universities, and the provinces.

Operational and work planning

Planning for 1989–1990 is following the format established for 1988–1989. The *Branch Head Plan* reflects Part 2 of the above-mentioned series, *Proposed Strategy—The Agriculture Canada (Research Branch) Perspective*. The *Branch Head Plan*, which responds to these directions, was completed in January 1988. This plan also identifies realigned branch priorities, incorporates policy issues affecting research, and provides direction for the preparation of work plans on a regional and establishment basis. An automated system has been developed so that the plans can be made available on Agrinet for searching and copying.

The following operational planning framework is being used by the branch for planning in 1988–1989:

1.0 Scientific research and development
1.1 Management and administration
1.2 Resource research
1.3 Animal research
1.4 Crop research
1.5 Food research

Full costing of work plans

A system has been implemented to determine the full cost of commodity research programs. For display purposes, overhead and indirect costs are allocated to obtain the "real" cost of doing business.

Reporting to Treasury Board and Parliament

On behalf of the Strategies and Planning Directorate, the division prepared the Research Branch sections in three departmental reports to Treasury Board and Parliament: the *Multi-Year Operational Plan*, the *Main Estimates Part III*, and the annual report for the Minister. These reports provide an opportunity for the branch to outline clearly its concerns, priorities, and resource needs for the upcoming fiscal year, and to describe its achievements of the previous year.

Quarterly reporting

The quarterly operational variance reports continued to be the main mechanisms for reporting achievements, variances against plans, and factors that may affect future progress across the branch. For the third and fourth quarters the *Branch Head Plan* has proved to be particularly useful for recording major management and operational achievements, as well as resulting client benefits and program effects.

Branch Secretariat

The Research Branch Secretariat continues to provide secretariat services to the Branch Executive Committee and the Research Branch Advisory Committee.

Research Program Service
Ottawa, Ontario

PROFESSIONAL STAFF

Administration

Y. Bélanger, B.Sc.	Director
H. Pitt, B.A.	Administration and awards

Art and Design

C.N. Halchuk	Head of Section

Audiovisual

W.G. Wilson	Head of Section

Scientific Editing

S.M. Rudnitski, B.Sc.	Acting Head of Section
J.T. Buckley,[1] B.A., M.A.	Editing
N. Rousseau, B.A., M.A.	Editing
F. Smith, B.A.	Editing

Scientific Information Retrieval

Head of Section	Vacant
H.S. Krehm, B.A., M.A., Ph.D.	Chief, Pest Management
C.D. Laing, B.Sc., M.Sc.	Chief, Inventory and Systems
P. Beauchamp, B.Sc., M.Sc.	Pest management
L. Boardman,[2]	Inventory and systems
J.R. Kennett, B.Sc.	Inventory and systems
E.K. McMillan, B.Sc.	Inventory and systems
R. McNeil, B.Sc.	Pest management

Departures

S.V. Balchin Retired 5 August 1988	Editing
D.R. Sabourin, B.A. Resigned 22 January 1988	Editing

[1] Appointed 17 August 1988.
[2] Appointed 4 January 1988.

INTRODUCTION

Research Program Service (RPS) supports research and development in the branch, as well as technology transfer and the spread of scientific knowledge. To do so, RPS maintains computerized scientific and technical information systems; provides publication, audiovisual, and art services; and administers jointly the programs for research partnership support and visiting fellowships.

The Art and Design Section provides the many different types of graphic arts and design services needed for publications, displays, posters, and other branch and departmental projects. The Audiovisual Section provides many audiovisual, computer graphic, and photographic services, including field and studio photography, and produces colored slides for presentations.

The Scientific Editing Section manages the publishing program for the Research Branch by planning, editing, producing, printing, and arranging for the distribution of about 100 publications annually on a wide variety of agricultural subjects.

The Scientific Information Retrieval Section provides access by computer to the latest information on agri-food research and pest management in Canada, including the current status of pesticides, pest management research, and biotechnology, and maintains an inventory of plant gene resources.

Further information can be obtained from the Director, Research Program Service, Research Branch, Agriculture Canada, Ottawa, Ont. K1A 0C6; Tel. (613) 995-7084.

Yves Bélanger
Director

ADMINISTRATION

RPS continued to administer the visiting fellowships during 1988 and assisted in the administration of the new research partnership support program (replacing the operating grants program). Research partnership support grants will be awarded to researchers at Canadian faculties of agriculture and veterinary medicine or to researchers collaborating with them toward the costs of proposed research projects that will benefit the agricultural industry and train graduate students. The new program, cofunded by the Natural Sciences and Engineering Research Council (NSERC), matches on a two-to-one basis funds committed by industry. The selection committee comprises five representatives from faculties of agriculture and veterinary medicine, two representatives from industry, three from Agriculture Canada, two appointed by NSERC, and one from the Canadian Agricultural Research Council.

The visiting fellowship program gives promising young scientists from around the world an opportunity to work with distinguished researchers in their respective fields before embarking on careers in scientific research. NSERC administers the program on behalf of Canadian government departments and agencies. RPS acts as liaison between the council and Agriculture Canada. In 1988, the selection committee received 36 applications for grants totaling $1 900 000.

ART AND DESIGN

Again during 1988 the Art and Design Section provided many varied art-related services to the branch as well as to other departmental agencies.

The section produced artwork for 116 publication projects, both branch and departmental; 71 seminar display projects; 598 jobs requiring preparation of charts, graphs, and scientific illustrations; and more than 2680 photomechanical transfer prints for art purposes and reproduction. These totals represent an increase of 40, 31, 6, and 34%, respectively, over the previous year.

In addition, the section oversaw the printing process for branch publications from printing requisitions to quality control.

The section also assessed several types of computer equipment packages in preparation for the introduction of computerized equipment, which will play an important role in future art services.

AUDIOVISUAL

The Audiovisual Section continued to provide a wide variety of photographic, computer graphic, and audiovisual services to the branch. In general, production levels throughout the section were much the same as the previous year; however, field photography returned to normal levels, and micro–macro photography was at an all-time high of 15 458 photographs, an increase of 110% over the previous year.

High-resolution, full-color, computer graphic slides continued to be in great demand. A heavier workload required the installation of a Starburst II computer, which is faster and offers additional editing features, such as automatic color shading and shadowing.

SCIENTIFIC EDITING SECTION

Scientific editors help authors communicate scientific and technical information to their intended readers. The editors evaluate the text and recommend changes to correct questionable statements and errors or inconsistencies in spelling, grammar, and presentation of scientific terminology. They also manage the design process and supervise typesetting, layout, and printing to ensure a level of quality suitable for the type of publication being produced.

Publications are produced by the most efficient and cost-effective method available, depending on the intended use. By developing new procedures to use electronic typesetting and page-layout systems now available, RPS cut the 1988 publications budget by about one-third.

Books, reports, and brochures written by branch scientists and accepted for publication by the department are divided into two main categories, branch and departmental.

Branch publications

Branch publications are directed to a narrow audience, which is either highly specialized or restricted to a specific locality. They are printed in small quantities using inexpensive methods and are distributed free by the issuing branch establishment. Branch publications are classed in five categories:

- technical bulletins, written for colleagues in a specialized field
- soil survey reports, written for specialists, planners, and managers of land resources in specific areas
- internal executive reports, issued by the branch executive or expert committees, usually in the form of planning documents, minutes, or proceedings
- historical publications, written to document the achievements of a specific program or establishment and of interest to readers in a restricted locality or brought together for a special event
- miscellaneous reports such as guides to research establishments, local or specialized newsletters, and specialized branch periodicals, written for a specific locality or a highly specialized readership.

In 1988, RPS produced 14 technical bulletins, 9 soil surveys, 20 internal executive reports, and 26 miscellaneous reports, for a total of 69 branch publications. Included among the lengthy branch publications edited and produced this year were

- *Land resource inventory of Mill and Woodfibre creeks*
- *Land resource inventory of the Power River watershed, B.C.*
- *Preliminary inventory and annotated bibliography of Canadian weeds*
- *Soils of the Gulf Islands of B.C., Vol. 2*
- *Soils of the Pasadena–Deer Lake area, Nfld.*
- *Soils of Prince Edward Island.*

Departmental publications

RPS also produced 29 departmental publications, including scientific monographs, reference books, or handbooks for the agricultural scientist or specialist; six were priced publications.

Priced departmental publications. Lengthy books, which are expensive to produce, are sold by Supply and Services Canada as priced departmental publications. Included in this group are scientific monographs, reference books, or handbooks written for the use of agricultural scientists or specialists.

In 1988, the following priced departmental publications were produced:

- *Canadian farm buildings handbook*
- *La ferme canadienne : Manuel de construction*
- *Guide to the identification of plant macrofossils in Canadian peatlands*
- *Guide illustré des macrofossilles des tourbières du Canada*

- *Les plantes nuisibles du Canada*
- *Wild rice in Canada.*

Free departmental publications. Departmental booklets are stored and distributed free by Communications Branch. In this group some of the titles produced last year in both official languages were

- *Commercial storage of fruits and vegetables*
- *Curing flue-cured tobacco*
- *Growing rutabagas*
- *Management of saline soils under irrigation*
- *Recommended code of practice for the care and handling of mink*
- *Recommended code of practice for the care and handling of special fed veal calves*
- *Reducing mycotoxins in animal feeds*
- *Reed canarygrass—a production guide.*

SCIENTIFIC INFORMATION RETRIEVAL

Inventory of Canadian Agri-Food Research

The Inventory of Canadian Agri-Food Research (ICAR) was updated in the course of the year. Additional information was collected on behalf of the Dairy Farmers of Canada (DFC) to assist in the compilation of the DFC annual report. Scientific Information Retrieval Section (SIRS) continued to provide access to this computerized data base across Canada to the whole research community as well as to Research Branch personnel. The 1988 version of ICAR provides information on over 4400 agri-food research projects. The distribution of research effort was tabulated by commodity and discipline in the ICAR summary tables, which were widely distributed.

Study data base

The study data base became operational in the spring and by year's end contained detailed information on over 900 studies from Research Branch establishments across Canada. Primarily a scientific reporting and retrieval system, the study data base provides information at both the establishment and headquarters level. It was developed in response to a recommendation in the Research Branch report entitled *Decision information systems planning.*

Pest Management Research Information System

All components of the Pest Management Research Information System (PRIS) were updated and maintained. PRIS continues to provide on-line access across Canada to current pest management research information. Studies are under way on the addition of several new components to PRIS, stressing the newer trends of biological control, biotechnology, integrated pest management, and nonpesticidal research to control plant and animal pests in agri-food production systems.

A new initiative was undertaken to transfer the PRIS information to the Canadian Centre for Occupational Health and Safety in Hamilton, Ont., and so to make the data base available on CCINFOline and compact disc both in Canada and internationally.

Other data bases

In response to a request from Research Branch headquarters, an inventory of Ph.D. graduate students was developed successfully. This computerized system allows planners to compare forecasted requirements for research scientists with the supply of qualified personnel graduating from universities.

The section is also providing programmer–analyst support to help develop a major data base for the plant gene resources protected by the Plant Research Centre. This data base will provide access to thousands of seed acquisitions in the national collections of gene resources. These seed samples are extremely important as a reservoir of genetic variability for the protection and maintenance of plant stocks.

Minor use program

The Minor Use of Pesticides Program continues to improve Canada's production capability for a wide range of crops and has brought about substantial gains for producers. It is an important production tool in the area of new programs of crop development. SIRS continued to administer the program and to coordinate the activities of the various agencies concerned. In 1988, 170 submissions to the program were received and 27 new uses were accepted for registration. In addition, a review of the Minor Use of Pesticides Program was completed for consideration by the management of Research and Food Production and Inspection branches. Reports on the minor use

program are disseminated to members of the agricultural industry, growers, scientists, and provincial extension specialists through the quarterly newsletter, *Pesticide Information*.

Canadian Plant Disease Survey

Research Program Service, in collaboration with the Canadian Phytopathological Society, published a special spring issue of the *Canadian Plant Disease Survey* on disease highlights of the previous year. The highlights covered the main horticultural and cereal crops, facilitating efforts to take remedial action to protect our crops from any harmful diseases that may occur or be introduced into Canada.

Committees

In addition to their regular activities, section staff supported the Expert Committee on Pesticide Use in Agriculture, the Expert Committee on Weeds, the Western Expert Committee on Grain diseases, the Eastern Expert Committee on Grains and Oilseeds, the Canada Committee on Crop Production, the Canada Committee on Food, the Canadian Horticultural Council, and the Canadian Standards Association.

Central Experimental Farm
Ferme expérimentale centrale

J.C. St-Pierre

P.B. Marriage

Director General	*Directeur général*	J.C. St-Pierre, B.Sc. (Agr.), M.Sc., Ph.D.
Program Director	*Directeur des programmes*	P.B. Marriage, B.Sc., Ph.D.

PREFACE

The directorate located at the Central Experimental Farm in Ottawa consists of the Animal Research Centre (ARC), Biosystematics Research Centre (BRC), Engineering and Statistical Research Centre (ESRC), Food Research Centre (FRC), Land Resource Research Centre (LRRC), and Plant Research Centre (PRC). In 1988, the programs were conducted by a complement of 971 person-years involving 276 professional staff. All the centres combine active research on programs that have national significance with linkage to other regional establishments and service to the agri-food sector in specialized areas of their research, including collaborative ventures with industry, provinces, and universities. Significant research accomplishments are highlighted in the reports of the individual centres.

The Animal Research Centre conducts research in animal biotechnology, which includes the fields of gene manipulation and rumen fermentation. Other significant research includes studies on animal behavior, environmental management of farm livestock, and the safety and quality of feedstuffs and animal products.

The Biosystematics Research Centre provides Agriculture Canada clients with a unique centre of systematic expertise for dealing with economic and social problems relating to insects, mites, spiders, plant parasitic nematodes, weeds, crop plants, native plants, plant parasitic and biodegrading fungi, and nonmedical bacteria. As the only Canadian organization with comprehensive collections, systematic research, and identification expertise, BRC continues to provide systematic services to support production and resource protection for two major Canadian industries, agriculture and forestry. Research activities have been progressively realigned in response to demands in areas such as integrated pest management, environmental protection, and biotechnology.

The Engineering and Statistical Research Centre provides the Research Branch with a centre of expertise where engineers and statisticians carry out research and analyses to improve agricultural and food production and inspection systems and to support research by other disciplines.

The Food Research Centre provides assistance to the food sector in improving its quality, marketability, and competitiveness. Research scientists work on developing new technology that enhances the safety, nutrition, and quality of food. Through a combination of in-house research, collaborative research projects, and technical advice, the Centre supports industry development and consumer protection.

The Land Resource Research Centre does research on soil, water, and agrometeorology and carries out soil surveys. The centre is responsible for collecting, assembling, and integrating information on soil, climate, and surface hydrology in Canada, as well as for undertaking research to assess and improve the potential of land for sustained agriculture and other land uses.

The Plant Research Centre has the mandate to develop, evaluate, and apply knowledge and technologies for crop improvement, crop protection, and plant health by integrating new biotechnological methods with conventional research approaches. PRC develops and releases elite genetic material and cultivars of selected crops and determines methods for pest management and increased resistance to stress. Programs in biotechnology generate knowledge and technologies for the characterization and manipulation at the cellular and molecular levels of agronomically important traits in crop plants. An understanding is being gained of important plant–microbe interactions, and determinants for plant growth enhancement and disease resistance are being elucidated. PRC houses the central office for the Plant Gene Resources of Canada and is also responsible for the management of the Central Experimental Farm.

Further information about our programs may be obtained by writing to the research establishments concerned or by addressing inquiries to the Central Experimental Farm, Research Branch, Agriculture Canada, Room 715, Sir John Carling Building, Ottawa, Ont. K1A 0C5; Tel. (613) 995-7084.

J.C. St-Pierre
Director General

PRÉFACE

La Direction située à la Ferme expérimentale centrale à Ottawa comprend le Centre de recherches zootechniques (CRZ), le Centre de recherches biosystématiques (CRB), le Centre de recherches techniques et de statistiques (CRTS), le Centre de recherches sur les aliments (CRA), le Centre de recherches sur les terres (CRT) et, enfin, le Centre de recherches phytotechniques (CRP). En 1988, la Direction a géré des effectifs de 971 années-personnes dont 276 professionnels. Tous les centres allient la recherche active dans le cadre des programmes nationaux aux besoins en recherches des régions et du secteur agro-alimentaire, et établissent des liens contractuels avec l'industrie, les provinces et les universités. Chaque centre souligne ses plus importantes réalisations dans son rapport annuel.

Au Centre de recherches zootechniques, les chercheurs axent leurs travaux sur la biotechnologie animale qui recouvre des domaines tels la manipulation génétique et la résistance aux maladies, aussi bien que la manipulation des gamètes et la fermentation du rumen. Ils se chargent également d'importantes études sur le comportement des animaux et sur les facteurs d'ambiance agissant sur les animaux de ferme et, enfin, sur la qualité et l'innocuité des denrées et produits animaux.

Le Centre de recherches biosystématiques offre aux clients de l'Agriculture Canada un centre unique d'expertise où l'on résoud les problèmes socio-économiques causés par les insectes, les acariens, les araignées, les nématodes parasites des végétaux, les mauvaises herbes, les plantes cultivées, les plantes indigènes, les champignons parasites des plantes et biodégradants et les bactéries dépourvues d'intérêt médical. Grâce à ces collections complètes, à son service d'identification et à sa capacité de recherches systématiques, le CRB peut dispenser aux deux grands secteurs canadiens que sont l'agriculture et les forêts, les services nécessaires à la production et à la protection des ressources. Face à la demande, il a progressivement réorienté ses travaux dans les domaines de la lutte anti-parasitaire intégrée, de la protection de l'environnement et de la biotechnologie.

Pour sa part, le CRTS dispense à la Direction générale des services d'experts-conseils; ses ingénieurs et ses statisticiens mènent des recherches et des analyses pour améliorer la production agro-alimentaire et le système d'inspection et pour appuyer des travaux dans d'autres domaines.

Le Centre de recherches sur les aliments s'intéresse au secteur des aliments surtout l'amélioration de la qualité, des possibilités de commercialisation et des facteurs compétitifs dans le cadre de programmes, de mise au point de techniques améliorées en vue d'accroître l'innocuité, la valeur nutritive et la qualité des aliments. Le Centre appuie la mise en valeur du secteur et la protection du consommateur par la recherche interne qu'il mène, les projets en collaboration et la prestation de conseils.

Le Centre de recherches sur les terres (CRT) s'occupe de programmes sur les sols, les eaux et l'agrométéorologie et des levés de recherche de terrains. Il veille à recueillir de l'information sur les sols, le climat et l'hydrologie de surface et à sa mise en forme, et effectue des recherches visant à évaluer dans quelle mesure les sols se prêtent à l'agriculture de conservation et à en accroître les possibilités d'utilisation.

Le Centre de recherches phytotechniques a pour mandat de développer, d'évaluer et d'appliquer les connaissances techniques à l'amélioration et à la défense des plantes cultivées en intégrant les techniques de biotechnologie aux méthodes plus conventionnelles. Le CRP produit des lignées nouvelles et des cultivars de cultures sélectionnées et allie les méthodes de lutte intégrée aux facteurs de résistance au stress. Les programmes de biotechnologie visent à améliorer les caractéristiques génétiques et moléculaires des plantes. Les chercheurs du Centre étudient davantage les relations d'interactions plantes–microbes, les facteurs de croissance et de résistance aux maladies. Le CRP comprend également le Bureau des ressources phytogénétiques du Canada. C'est aussi le centre d'administration de la Ferme expérimentale centrale.

Pour obtenir de plus amples renseignements sur nos programmes, il faut écrire aux établissements de recherches concernés ou adresser vos demandes à la Direction de la Ferme expérimentale centrale, Direction générale de la recherche, Agriculture Canada, Édifice Sir John Carling, Pièce 715, Ottawa, (Ont.) K1A 0C5; Tél. (613) 995-7084.

J.C. St-Pierre
Directeur général

Animal Research Centre
Ottawa, Ontario

PROFESSIONAL STAFF

Administration

E.E. Lister,[1] B.Sc., M.Sc., Ph.D.	Director
J.I. Elliot,[2] B.S.A., M.Sc., Ph.D.	Deputy Director
S.K. Ho,[3] B.Sc., Ph.D.	External Project Officer
D.A. Leger, B.Sc.	Assistant to the Director
D.A. Schmid, B.A.	Chief, Administration and Resources
L.M.B. Babin, B.A.	Administrative Officer, Personnel
J.G.R. Boisclair	Administrative Officer, Finance

Scientific Support

K.G. Hilson, B.Sc., M.Sc.	Project Manager; Computer services
D. Campbell	Programmer–Analyst
B.J. McKelvey	Programmer–Analyst
H.M. Mucha	Programmer–Analyst
T.D. Osterhout	Programmer
K.E. Hartin, D.V.M.	Veterinarian
J.P. Miska,[4] B.A., B.L.S.	Library services

Biotechnology

J.S. Gavora,[5] Ing., C.Sc.	Program Chairperson; Disease resistance genetics
D.E. Bernon, B.Sc.(Agr.), M.Sc., Ph.D.	Molecular and quantitative genetics
P.S. Fiser, B.Sc., M.Sc., Ph.D.	Cryopreservation, male reproductive physiology
A.J. Hackett, D.V.M., M.Sc., Ph.D.	Embryo transfer, female reproductive physiology
M. Lessard,[6] Bacc., M.Sc.	Nutrition and immunology
G.J. Marcus, B.A., Ph.D.	Reproductive physiology, embryo manipulation
J. Nagai,[7] B.Sc., D.Agr.	Embryo manipulation, quantitative genetics
M.P. Sabour,[8] B.Sc., Ph.D.	Molecular and cellular genetics
R.M. Teather, B.Sc., Ph.D.	Molecular biology and genetic manipulation of rumen bacteria

Animal Waste Utilization

N.K. Patni, B.Ch.E., M.Sc., Ph.D.	Program Chairperson; Livestock waste utilization, farm pollution abatement

Dairy and Beef Cattle Nutrition

M. Ivan, Ing., M.Sc., Ph.D.	Program Chairperson; Digestive physiology, ruminants
A.S. Atwal, B.Sc., M.Sc., Ph.D.	Forage evaluation and nutrition
J.D. Erfle, B.S.A., M.Sc., Ph.D.	Rumen metabolism and nutrition

M. Hidiroglou, D.V.M., Dip. Nutr.	Vitamin and trace mineral nutrition
K.J. Jenkins, B.S.A., M.Sc., Ph.D.	Calf nutrition
S. Mahadevan, B.Sc., M.Sc., Ph.D.	Rumen metabolism and nutrition
F.D. Sauer, D.V.M., M.S., Ph.D.	Rumen metabolism and nutrition
D.M. Veira, B.Sc., M.Sc., Ph.D.	Ruminant nutrition

Dairy Cattle Breeding and Production

A.J. Lee,[9] B.Sc.(Agr.), Ph.D.	Program Chairperson; Dairy cattle breeding and production—statistical methodology and breeding strategies
T.R. Batra,[10] B.V.Sc., M.V.Sc., M.S., Ph.D.	Dairy cattle breeding—field data analyses, disease resistance
C.Y. Lin, B.S., M.S., Ph.D.	Dairy cattle breeding—multi-trait mixed model sire and cow evaluation methods; computer modeling
A.J. McAllister, B.S., M.S., Ph.D.	Dairy cattle breeding and production—selection for lifetime performance and use of crossbreeding

Swine Production

D.W. Friend, B.Sc., M.Sc., Ph.D.	Program Chairperson; Sow and piglet production, mycotoxins
A. Fortin, B.Sc.(Agr.), Ph.D.	Carcass composition, quality—swine, poultry, sheep, cattle
D.G. Fraser, B.A., Ph.D.	Animal behavior—swine, sheep

Poultry Breeding

A.A. Grunder, B.S.A., M.Sc., Ph.D.	Program Chairperson; Eggshell quality genetics, broiler breeding, goose breeding and management
J.R. Chambers, B.Sc., M.Sc., Ph.D.	Broiler breeding and management
R.W. Fairfull, B.Sc., M.Sc., Ph.D.	Egg stock breeding and management
C.P.W. Tsang, B.Sc., M.Sc., Ph.D.	Physiology—eggshell quality and egg production

Poultry Nutrition

I.R. Sibbald, B.Sc.(Agr.), M.Sc., Ph.D., D.Sc.	Program Chairperson; Nutrient requirements and feedingstuff evaluation
N.A.G. Cave, B.Sc., M.Sc., Ph.D.	Broiler breeder nutrition and management, evaluation of novel feedingstuffs
R.M.G. Hamilton, B.Sc.(Agr.), M.Sc., Ph.D.	Nutrition and physiology—minerals, mycotoxins

Sheep Production

L. Ainsworth, B.Sc., M.Sc., Ph.D.	Program Chairperson; Female reproductive physiology
D.P. Heaney, B.S., M.S., Ph.D.	Nutrition and intensive management
G.A. Langford, B.Sc., M.Sc., Ph.D.	Male reproductive physiology
J.N.B. Shrestha, B.V.Sc.A.H., M.S., Ph.D.	Breeding and intensive production—applied quantitative genetics

Animal Feed Safety and Nutrition

H.L. Trenholm, B.Sc.(Agr.), Ph.D.	Program Chairperson; Mycotoxins, toxicology
M.H. Akhtar, B.Sc., M.Sc., Ph.D.	Pesticide metabolism and residues

E.R. Farnworth, B.Sc., M.Sc., Ph.D.	Lipid nutrition and perinatal metabolism
J.K.G. Kramer, B.Sc., M.Sc., Ph.D.	Lipid chemistry and biochemistry
D.B. Prelusky, B.Sc.(Pharm.), Ph.D.	Mycotoxin metabolism, toxicology

Departures

L.M. Coté,[11] B.Sc., M.Sc., Ph.D. Terminated service 8 April 1988	Biochemical toxicology, mycotoxins
J.R. Lessard,[12] B.A., B.S.A., M.S., Ph.D. Retired 31 December 1988	Forage conservation and nutrition

VISITING SCIENTISTS

L.L. Charmley, B.Sc., Ph.D. Institute for Research on Animal Diseases, Compton, UK	Copper metabolism
Y. Fukuma Nihon Nosan Kogyo Feed Research Centre, Ibaraki, Japan	Feed evaluation methodology
S. Gamage, B.Sc. Central Poultry Research Station, Kundasala, Sri Lanka	Poultry breeding
P. Javorsky, Ph.D. Institute of Animal Physiology, Slovak Academy of Sciences, Kosice, Czechoslovakia	Rumen bacteria plasmid vectors
K. Nonaka, Ph.D. Kyushu University, Fukuoka, Japan	Transfer and manipulation of embryos
R.A.E. Pym, Ph.D. Department of Animal Sciences and Production, University of Queensland, Brisbane, Australia	Broiler breeding and selection
R.G. Warnock, B.Eng., Ph.D. Department of Civil Engineering, University of Ottawa, Ottawa, Ont.	Waste disposal and surface and groundwater pollution

Natural Sciences and Engineering Research Council of Canada postdoctorate fellows

E. Charmley,[13] B.Sc., Ph.D., 1987–1988	Forage evaluation
G. Davis, B.Sc., Ph.D., 1986–1988	Mouse embryo transfer, transgenic mice
D. Denicourt, B.Sc., M.Sc., Ph.D., 1987–1989	Molecular genetics—analysis of casein genes
S.N. Liss, B.Sc., M.Sc., Ph.D., 1987–1988	Molecular biology of rumen bacteria
H.S. Sasada, Ph.D., 1988–1989	Embryo manipulation

Canadian International Development Agency (CIDA) trainees (Canada–Brazil Project)

L. Aroeira, M.Sc., Ph.D. National Dairy Cattle Research Centre (CNPGL), Coronel Pacheco, Brazil	Dairy cattle nutrition
H.C.V. Codagnone, M.Sc. Parana State Agricultural Research Institute (IAPAR), Londrina, Brazil	Dairy cattle nutrition

M.S. Dayrell, B.Sc., D.Sc. National Dairy Cattle Research Centre (CNPGL), Coronel Pacheco, Brazil	Ruminant mineral nutrition
C.M. Jaume, B.Sc.(Agr.Eng.), Ph.D. National Dairy Cattle Research Centre (CNPGL), Coronel Pacheco, Brazil	Dairy cattle reproductive physiology
M.L. Martinez, B.S., M.S., Ph.D. National Dairy Cattle Research Centre (CNPGL), Coronel Pacheco, Brazil	Dairy cattle breeding and selection

Research associates on contract

G. Herbert,[14] Ph.D.	Poultry pedigree records systems
L. Sliger,[15] B.Sc.	Dairy cattle breeding
L. Underhill,[16] M.Sc.	Frozen boar semen evaluation

Graduate students

M.L. Biehl, D.V.M.	Mycotoxin metabolism
H.C. Gauvreau, D.V.M.	Vomitoxin metabolism
E.A. Pajor,[17] B.Sc.	Swine behavior

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1 Seconded to Headquarters, Research Branch, 6 August–28 October 1988, 21 November–30 December 1988.
2 Acting Director, 6 August–28 October 1988, 21 November–30 December 1988.
3 Seconded from Feed and Fertilizer Division, Food Production and Inspection Branch, from 1 February 1988. Acting Deputy Director, 6 August–28 October 1988, 21 November–30 December 1988.
4 Seconded from Libraries Division, Corporate Management Branch.
5 On transfer of work at Molecular Genetics Laboratory, National Research Council of Canada, Ottawa, Ont., 6 April 1987–31 March 1988. At Hiroshima University, Fukuhama, Japan, as recipient of a fellowship from the Japan Society for the Promotion of Science, 1 September–15 October 1988.
6 Appointed 16 May 1984. On doctorate training program at the University of Wisconsin, Madison, and Laval University, Quebec, until 8 June 1988.
7 Acting Program Chairperson, 6 April 1987–31 March 1988.
8 Acting Program Chairperson, 1 September–15 October 1988.
9 On transfer of work at Department of Animal and Poultry Science, University of Guelph, Guelph, Ont., 1 September 1988–30 April 1989.
10 Acting Program Chairperson, 1 September 1988–30 April 1989.
11 On extended leave at the University of Illinois, Urbana, from 7 March 1987.
12 Seconded to Headquarters, Research Branch, since 1 November 1981.
13 Funded by the Canada–Brazil Project, CIDA, Ottawa, Ont., from 1 April 1988.
14 Funded by Shaver Poultry Breeding Farms Ltd., Cambridge, Ont.
15 Funded by the Canada–Brazil Project, CIDA, Ottawa, Ont.
16 Funded by the Ontario Pork Producers Marketing Board, Toronto, Ont.
17 Partial funding by the Ontario Pork Producers Marketing Board, Toronto, Ont.

INTRODUCTION

As a national centre for animal research, the role of the Animal Research Centre (ARC), Ottawa, is to identify and solve problems associated with improving livestock and poultry production in Canada. ARC has a multidisciplinary program team structure consisting of researchers with a broad range of scientific knowledge. Both applied and basic studies are under way.

ARC is a Canadian centre of expertise in the area of animal biotechnology, which includes the fields of gene manipulation, disease resistance, gamete manipulation, and rumen fermentation. Other significant research areas include studies on animal behavior and environmental management of farm livestock, and on the safety and quality of feedstuffs and animal products. Within these three broad areas are important individual studies on the dietary utilization of fats and oils; pesticide metabolism and residues; animal waste utilization; reproductive physiology; carcass evaluation; ruminant digestive physiology; trace mineral and vitamin requirements; evaluation of new feedstuffs; and nutrition and management of dairy and beef cattle, sheep, swine, and poultry.

In addition to the federally funded research in progress at ARC, a number of clients participate in formal research partnerships. Amlin Grain Roasting Ltd., BASF Canada Ltd., the Canadian Association of Animal Breeders, Competitive Edge Crop Management Systems Inc., Daco Laboratories, Harshaw Chemicals Canada Ltd., and Hoffman-LaRoche Ltd. have provided important additional resources for new and continuing studies. Significant support is also provided by the Ontario Pork Producers Marketing Board, the Agricultural Research Institute of Ontario (Ontario Ministry of Agriculture and Food), the Canadian Meat Council, and Shaver Poultry Breeding Farms Ltd. who are predominant partners in several research areas. This increased collaboration with, and support by, industry is being achieved in line with the program thrusts of the Research Branch and the department.

The effective transfer of research findings from the laboratory to the agri-food industry continues as a major priority. In 1988, the technical bulletin *Feeding and care of young replacement veal calves* was published and received wide distribution. Collaborative research between the Plant and Animal Research centres was summarized in the departmental bulletin *Reducing mycotoxins in animal feeds*, and more than 6000 copies were forwarded to producers and extension specialists. Research findings were published in 62 scientific and 65 technical and popular press articles. Among the visitors to ARC and the Greenbelt Research Farm, the centre was especially honored by the Brazilian agricultural attaché and by members of a poultry mission from Indonesia. Numerous other Canadian and international scientists, extension workers, administrators, and livestock and poultry producers interacted with various staff and toured the laboratory and farm facilities.

The centre continued participation in the cooperative research and development program with Brazil in the area of dairy cattle production. The project is with the Dairy Research Centre of the Brazilian National Agricultural Research Organization and its state counterpart in Parana and is funded by the Canadian International Development Agency (CIDA). Five Brazilian researchers returned to Ottawa to continue collaborative research and training with ARC geneticists, nutritionists, and physiologists. The return to Venezuela of a number of Criollo cattle marked the end of a unique breeding project, which had examined milk production of this breed and three-way crossbreds under Canadian management conditions.

Several ARC scientists received major national or international awards in recognition of research excellence. Dr. Friend was honored by the Canadian Society of Animal Science certificate of merit for his studies in pig nutrition and management. The Canadian Association of Animal Breeders presented their award for excellence in genetics and physiology to Dr. Lee for his research in dairy cattle breeding and selection. At the congress of the World's Poultry Science Association in Japan, the association created an international poultry hall of fame to recognize world leaders in the industry. Elected as a founding member was Dr. Sibbald, whose system for measurement of true metabolizable energy in poultry feedingstuffs has been implemented around the world. Also elected to the hall was Dr. Gowe, recently retired director of ARC and an international authority on poultry breeding.

The national and international scientific communities continue to acknowledge the expertise of ARC researchers. Typical of this recognition was the invitation by the Organization for Economic Cooperation and Development (OECD) and University of New England, Armadale, Australia (UNE) to Dr. Ivan to chair an international seminar on the role of protozoa and fungi in ruminants, which was held in Australia; Dr. Prelusky was a featured speaker at an international conference on mycotoxin problems sponsored by the International Development Research Centre (IDRC) in Argentina; and Dr. Gavora chaired the section on disease resistance at the World Congress on Sheep and Beef Cattle Breeding in Paris. ARC scientists also provided input on program evaluation. Dr. Elliot was a member of the international team examining progress of the joint program of the Southern Africa Development Coordination Council (SADCC) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) for sorghum and millet improvement in the southern African states. Dr. Sibbald traveled to Argentina on behalf of the Inter-American Institute for Co-operation on Agriculture (IICA) to assess feedingstuff evaluation; closer to home Drs. Lister and Gavora assisted the Government of Quebec in its program of research grant evaluation.

Year 1988 marked important steps forward for the biotechnology program team. All three components (microbial genetics, embryo manipulation, and molecular genetics of livestock) now have laboratory facilities that meet minimum requirements. Despite occasional handicaps, significant progress has been made by the team. A major undertaking of the program was organizing the "Short course on molecular genetics applied in animal breeding and production," which took place in Guelph in July. The course, held in collaboration with the National Research Council of Canada and the University of Guelph, was attended by 48 participants; 22 from Canada, 11 from the United States, and 15 from nine other countries. Participants included geneticists from industry, university, and government laboratories. Twenty speakers provided an overview of the present state of biotechnology and discussed future prospects in a broad range of areas, including animal welfare and legal regulatory issues.

Further strengthening of the biotech program was accomplished with the return of Martin Lessard from a Ph.D. training program initiated by the Research Branch in 1984. Work in the area of gene manipulation and disease resistance will be expanded as his research program is established.

With the support and close collaboration of the Canadian Sheep Breeders Association, the synthetic sheep strains developed at the centre were registered as three new breeds and the process was started to disperse foundation animals to nucleus flocks across Canada. The Royal Agricultural Winter Fair saw the first public display of the ARCOTT breeds and their auction as breeding stock. Final testing and crossing of the breeds is under way as the breed development aspect of the sheep production program enters its last phase. An example of this testing was the transport of 58 ARCOTT sheep to the University of Minnesota to participate in evaluation of their milk production potential in comparison with numerous other established breeds.

This annual review highlights research for 1988. Some studies that have produced particularly noteworthy results include the following: the role of relaxin has been further clarified and its presence detected in follicular growth and ovulation; the usefulness of manipulating photoperiod to advance the age at puberty has been shown in growing lambs; genetic gains for broilers can be significant if emphasis is put on weight-corrected feed efficiency; studies on management of intensively housed geese showed good production of semen by ganders under a regimen of controlled light; detailed studies continued to unravel the problem as to why some egg-laying strains of chickens are resistant to the eradication of lymphoid leukosis; a new farrowing crate has been designed to allow the sow greater movement; the consumption of water by newborn piglets has been monitored and is shown to be essential for good growth and survival; naked oats with a lysine supplement supports good growth and carcass quality for growing–finishing pigs; in the diets of broiler chicks, vitamin supplementation of naked oats is useful to avoid effects of growth depression; manipulation of light and feed intake with broiler breeders as they approach adulthood reduces mortality and increases adult egg numbers; confirmation that the extensive metabolizable energy data for poultry feedstuffs can be extended for use with swine will expand the already widespread use of the true metabolizable energy–cockerel assay; initial studies with Jerusalem artichoke flour have indicated its possible use in milk replacer for piglets; metabolism

of a primary metabolite of a popular, synthetic pyrethroid insecticide has indicated that the parent chemical is not a danger to the poultry industry; many pharmacologic effects of mycotoxins occur at the cellular level, which confirms the need to remove or destruct the toxin in grain prior to consumption; 18 synthetic genes have now been designed to modify the composition of amino acid of rumen bacteria; for the first time foreign DNA has been introduced into a rumen bacterium and expressed in a stable way; pregnancies in cattle have been confirmed from embryo manipulation techniques involving nuclear transfer (cloning); genetic markers have been found that may be useful in selection for resistance to Marek's disease in poultry; selection for increased frequency of the κ-casein B allele can improve lifetime total yield of milk in dairy cattle; study of the effects of copper in calf diets has shown that intake should be at 10–50 ppm to achieve best performance; copper metabolism is also affected by rumen protozoa, however, the mechanism is indirect and depends on the type of protein consumed; the usefulness of vitamin E was established as an agent to prevent autoxidation of milk during storage; and the characteristics of a cytoplasmic cofactor that regulates synthesis of rumen bacterial methane has been determined, which could allow more efficient feeding of dairy cattle through reduced energy wastage via methane production.

Detailed information on the research accomplishments, methodology, and results can be obtained from the publications listed at the end of this report. Reprints of these publications and copies of this report are available on request from the Director, Animal Research Centre, Research Branch, Agriculture Canada, Ottawa, Ont. K1A 0C6; Tel. (613) 993-6002; Fax (613) 995-8175.

E.E. Lister
Director

BIOTECHNOLOGY

Genetic manipulation of rumen bacteria

Genetic engineering techniques continue to be applied to rumen bacteria to improve the efficiency of feed utilization by ruminants. The DNA sequence of the gene for a (1→3)(1→4)-β-D-glucanase from *Bacteroides succinogenes* cloned in *Escherichia coli* has been determined. Information on the detailed structure of the control region of this gene has been applied to the design of a plasmid cloning vector, which will facilitate the expression of foreign proteins in rumen bacteria.

E. coli clones that produce β-glucosidase and contain genes from the dominant rumen bacteria *Selenomonas ruminantium*, *Lachnospira multiparus*, and *Bacteroides succinogenes* have been studied to determine the substrate specificity of the enzymes. The isolation and analysis of genes from rumen bacteria for these enzymes, which are involved in the degradation of cellulose and other components of plant fiber, provide basic information about, and tools to modify, the extent and rate of degradation of plant fiber in the rumen.

The structure of 18 synthetic genes designed to reduce the need of ruminants for supplemental dietary protein has been confirmed by DNA sequence analysis. The gene products are being characterized and vectors for the cloning and expression of these genes in rumen bacteria are being developed. For the first time, foreign DNA has been introduced into a rumen bacterium and expressed in a stable way. The technique of electroporation was used to introduce a newly designed plasmid vector carrying a mixed-linkage β-glucanase gene into *Bacteroides ruminicola*. The plasmid was stably inherited and the glucanase gene was expressed in its new host.

Embryo manipulation and cryopreservation

Manipulation. The cloning of bovine embryos by the technique of nuclear transfer has been accomplished. Cows designated as egg and embryo donors were given hormone treatments to produce newly ovulated eggs and four to eight cell embryos at the required time. Blood progesterone levels were monitored continuously by enzyme immunoassay to confirm response to treatment and to verify the time of estrus. Embryos and oocytes were collected from the oviducts within 10 min after slaughter.

Micromanipulation procedures have been developed to separate blastomeres and enucleate the oocytes, removing the polar body and adjacent cytoplasm containing the metaphase chromosomes. A blastomere inserted beneath

the zona pellucida of an enucleated oocyte was fused to the oocyte by electrofusion. Fusion products were embedded in agar cylinders and placed in the oviducts of a sheep for in vivo culture. After 5 days, the agar cylinders were recovered, the embryos were removed, and those considered viable were transferred non-surgically into the uterus of prepared recipient heifers. To date, three pregnancies (>55 days) derived from one donor embryo have been confirmed.

Microsurgically bisected embryos are now used routinely for transfers by commercial cattle breeders. Measures of performance, such as body growth and milk production in cattle that have developed from bisected embryos, are not well known. Using mice as a pilot organism, experiments have examined viability of bisected embryos during gestation and postnatal growth and reproduction. Studies using inbred, outbred, and crossbred mice revealed that bisection decreased embryo survival during gestation by almost 20% compared with that of transferred whole embryos. It also increased the gestation period of recipients by 1.1 days, but did not affect postnatal growth or reproduction of males and females.

Cryopreservation. Preliminary experiments on the development of nontoxic diluents for the preservation of embryos at low temperatures without freezing (i.e., supercooling) have been completed and results are being summarized.

Studies to determine the optimal conditions for ultralow temperature preservation of boar semen have examined the interaction of glycerol concentration (0–100%) and cooling velocity (2–1500°C/min) and their effects on motility and acrosomal integrity of spermatozoa. The percentage of motile spermatozoa after freeze–thaw increases with greater glycerol concentration, the optimal glycerol concentration being determined by the freezing velocity used. However, the percentage of spermatozoa with a normal apical ridge (NAR) decreases with increasing concentration of glycerol. At the optimal freezing velocity of 30°C/min, boar spermatozoa can tolerate the higher levels of glycerol (4% v/v) necessary for adequate cryopreservation with only a slight decrease in NAR. The proportion of motile spermatozoa doubles compared to values obtained from current procedures using pellets on dry ice. To accelerate the evaluation of freeze–thaw damage in boar spermatozoa, the thermoresistance test was modified. Post-thaw incubation of spermatozoa at 42.5°C for 45 min is now used as a supplementary test to predict the fertilizing capacity of ejaculates processed by various procedures.

Disease resistance and molecular genetics

Lymphoid leukosis (LL) is a lymphoproliferative disease of chickens caused by a retrovirus. Resistance to LL virus infection is inherited. Viral penetration of the host cells involves interaction of a viral glycoprotein and a cell receptor. Affinity binding of LL virus with actylglucoside-extracted and radiolabeled proteins from the cell surface of susceptible embryonic fibroblasts, after chemical linking and immunoprecipitation, revealed four cellular proteins that bind specifically to the virus. Of these, one protein with apparent molecular mass of 68–80 kilodaltons was predominant. In another approach, electrophoretically separated and membrane-blotted cell surface proteins were probed with radiolabeled LL virus. Two autoradiographic viral bands were detected that interacted with cellular proteins.

Marek's disease (MD), caused by a herpes virus, results in development of tumors on nerves, viscera, and other sites. Despite vaccination, significant losses from MD persist, especially where highly virulent strains of the virus are involved. T-cells are the target of the neoplastic transformation by MD viruses and are also involved in cell-mediated immune response. Collaborative research with the Animal Diseases Research Institute, Nepean, Ont., and Hiroshima University, Higashi Hiroshima, Japan, compared resistance to MD in a variety of genetic groups of chickens. The study examined their protection by vaccination, as well as response to phytohemaglutinin (PHA), an indicator of cell-mediated immune response. Regardless of level of genetic resistance, vaccination reduced MD by about 70%. Hence, the lowest incidence of MD was in genetically resistant, vaccinated groups. Response to PHA was generally positively correlated with MD resistance but the correlation coefficients were not sufficiently large and constant to provide conclusive evidence on the relationship of genetic resistance to MD and response to PHA.

Collaborative research with Macdonald College of McGill University showed that DNA fingerprinting, based on the detection of a hypervariable virus satellite region in DNA restriction fragments can be succesafully

applied in chickens. Comparisons of the banding patterns between parents and offspring revealed that the bands are inherited as stable, Mendelian traits. As expected, the variability of the DNA fingerprinting patterns was reduced in inbred lines. Indices of genetic distance computed on the basis of the DNA fingerprints for five well-defined genetic groups correctly reflected the history of the groups. It was concluded that DNA fingerprinting may be a powerful tool to characterize genetic relationships among populations.

Studies with Macdonald College also resulted in progress towards development of DNA probes for genetic loci associated with MD resistance. A DNA polymorphism was detected, through the use of a cloned *C-myb* oncogene probe, between strains of chickens previously selected for resistance or susceptibility to MD. DNA fingerprinting, using phage M13 as a probe, revealed a highly amplified DNA segment of about 20 kilobases present in MD-resistant chickens and absent or present only at a low frequency in susceptible birds. These two genetic markers may be useful for selection for MD resistance without deliberate exposure of the selection candidates to the virus.

DAIRY CATTLE BREEDING

Genetic evaluation procedures

Simulation results from a cooperative project between ARC and the record of performance program of the Livestock Development Division demonstrated that correlations between true and estimated genetic values are higher when several traits are analyzed simultaneously than when done individually. However, the advantage of multiple- over single-trait analysis appeared small in both random or selected populations when the traits studied were highly positively correlated. Further study is currently under way to examine the differences when the traits involved are negatively correlated.

Association of milk protein type with lifetime production

Data from 889 cows at five research stations of Agriculture Canada were used to study the effects of α-, β-, and κ-casein and β-lactoglobulin loci on lifetime performance representing first three-parity and 61-month total milk yields. Of the four types of milk protein, only the κ-casein locus was found to have significant effects on lifetime performance. Complete replacement of A by B allele at the κ-casein locus resulted in increases of 1657 and 1923 kg in first three-parity and 61-month total milk yields, respectively. It was concluded that the moderate gene frequency of κ-casein B allele in the current dairy population can be increased to improve lifetime total milk yield to the benefit of the dairy industry.

Bovine lymphocyte antigen (BoLA)

Blood samples from 271 Holstein AI bulls were typed for 37 antigens, controlled by codominant alleles of the BoLA locus, to study the relationships of BoLA alleles with estimated transmitting abilities (ETA) for production and type traits. Only 16 antigens were present and there were differences in the frequencies of the 16 associated alleles. The most common allele was W6.1, which had an allelic frequency of 26.0%. Substitution of W6.1 for W10 significantly ($P < 0.05$) increased the ETA for protein yield by 3.2 BCA (breed class average). The substitution of W11 allele for W10 significantly increased the ETA for yields as well as percentages of fat and protein. Substitution of W16 for W10 had a significant ($P < 0.05$) negative effect on most of the type trait proofs. The effect of BoLA allele on estimated transmitting ability in AI bulls suggested that the substitution of either W6.1 or W11 for W10 was significantly associated with increased yield of protein. Although not significant, the same substitution was associated with increased milk yield. It is now important to see if a similar association exists in other dairy populations.

National cooperative dairy cattle breeding project

Results of first lactation feed efficiency on about 3200 heifers showed significant line (H, A, or C) and breed source additive effects within line. Heterotic and maternal effects were generally unimportant. Feeding concentrates according to milk production level precluded clear separation of effects of yield, consumption, and initial weight on feed efficiency. Ayrshires were more efficient than Holsteins. The North American Ayrshire, Finnish Ayrshire, and Norwegian Red breed source additive effects on feed efficiency were superior to that of Agriculture Canada Holsteins with other genetic groups being intermediate.

DAIRY AND BEEF CATTLE NUTRITION

Composition of preruminant calf bile

In adult ruminants, lysophosphatidylcholine in bile promotes the intestinal solubilization and absorption of free palmitic and stearic acids, the products of fat metabolism in the rumen. Little is known of bile composition and function in the preruminant calf, which digests fat to monoglycerides and free fatty acids, as do monogastric animals.

Experiments demonstrated that bile from preruminant calves, fed milk replacer to 6 weeks of age, had similar patterns for lipids and bile acids as reported by others for adults. Taurocholic acid was the most abundant bile acid and taurine conjugates predominated over glycine conjugates. Phosphatidylcholine was the major lipid (~75%) with smaller amounts of phosphatidylethanolamine, sphingomyelin, lysophosphatidylcholine, triglycerides, free fatty acids, and cholesterol. The fatty acid composition of biliary phosphatidylcholine was found to be markedly affected by dietary fatty acids. Dietary essential fatty acids appeared in the biliary phosphatidylcholine but not in the essential fatty acid metabolites formed in the calf.

Copper in calf diets

The maximum safe level for Cu in calf milk replacers is not well defined. An upper limit of 10 ppm (in dry matter), recommended by the United States National Research Council, is based on very little experimental evidence. A 6-week feeding experiment with calves estimated the highest safe level of Cu in milk replacers containing 10, 50, 200, 500, or 1000 ppm Cu as sulfate. Weight gains, feed intake, and feed efficiency were the same for 10 and 50 ppm Cu. At 200 and 500 ppm, gains were reduced by 20 and 30%, respectively, and feed efficiency was much poorer than for 10 or 50 ppm. The calves could not tolerate 1000 ppm; three of the seven calves died and the four survivors had no weight gains. The calves showed typical symptoms of chronic Cu toxicity—apathy, poor appetite, jaundice, and brownish-red urine. Post-mortem examinations revealed that all calves fed 1000 ppm had typical signs of Cu toxicity. Carcasses of calves fed 500 ppm Cu were mildly affected but carcasses were normal for all those fed less Cu.

Supplementing the 1000 ppm Cu diet with 1000 ppm Zn prevented deaths but calf performance remained very poor. Most of the supplemental dietary Cu was found in the liver. Molybdenum (Mo) and Zn, trace elements that provide some protection against Cu toxicity, were in lowered concentrations in liver because of increased fecal excretion.

Although an intake of 50 ppm Cu was safe and allowed good calf performance, likely there are no benefits from providing more Cu in calf milk replacers than the United States National Research Council recommendation of 10 ppm. On the contrary, where milk replacers contain less Zn and Mo than used in this experiment and the feeding period is longer as in veal production, calves would be much more susceptible to Cu toxicity.

Ciliate protozoa and copper availability

Ciliate protozoa are part of the ruminal ecosystem and affect ruminal metabolism. It was found previously that the presence of ciliate protozoa in the rumen reduces the bioavailability of Cu in diets containing soybean meal (SBM) as supplementary protein and that this reduction is not dependant on the dietary concentration of Cu. Further experiments with fauna-free and faunated sheep studied the effects of protozoa on the bioavailability of Cu in corn silage, alone and with SBM, casein, or fish-meal supplements. The faunated sheep in all treatments grew faster and consumed more feed and consequently more Cu. However, they had a significantly lower ruminal Cu solubility and accumulated less Cu in their livers than the fauna-free sheep when fed corn silage alone or in combination with SBM—an insoluble, rumen-degradable protein. Such effects were not significant when corn silage was supplemented with fish meal, a partially rumen-degradable protein. The presence of ciliate protozoa in the rumen had no effect on the accumulation of Cu in the liver of sheep fed corn silage supplemented with casein—a soluble, rumen-degradable protein. The results showed that the effect of protozoa upon Cu metabolism is indirect and depends on the type of dietary protein present.

Vitamin D supplementation

Plasma concentrations of vitamin D_3 (D_3) and 25-hydroxyvitamin D_3 (25-OHD_3) were measured serially in confined sheep that had been supplemented either with dietary D_3 or

exposed daily to ultraviolet irradiation (UVI). In sheep receiving oral D_3, plasma levels of the vitamin increased continuously until a plateau was reached after 56 days of supplementation. Plasma 25-OHD_3 concentrations also increased continuously and plateaued between 65 and 75 days. In UVI sheep, plasma D_3 and 25-OHD_3 concentrations increased continuously for the first 49 days, then plateaued.

Following its administration intravenously, labeled 25-OHD_3 was found to be eliminated more rapidly after a high oral intake of D_3, resulting in a shorter life of the vitamin compared with that in UVI sheep. The turnover rate of 25-OHD_3 was slower in sheep receiving UVI. It was concluded that the differences in turnover rates were reflected by differences in inter-compartmental transfer rates. The data indicated that UVI was more effective than oral D_3 supplementation for improving of vitamin D status of confined sheep.

Vitamin E pharmacokinetics

The pharmacokinetic disposition of various tocopherol (vitamin E) formulations were studied in sheep when the various tocopherol preparations were given orally in equivalent international units. The efficacy of α-tocopherol (natural form) was greater than that of D-α-tocopherol, DL-α-tocopherol acetate, D-α-tocopherol acetate, or DL-α-tocopherol. When administered intravenously, D-α-tocopherol acetate was more effective than equivalent amounts of DL-α-tocopherol acetate or DL-α-tocopherol.

Autoxidation of milk and vitamin E

Milk containing milk fat with levels of α-tocopherol less than 20 μg/g is likely to oxidize and flareups of autoxidation during storage in the food distribution system are becoming common. Cows are inefficient in transferring dietary vitamin E, a natural antioxidant, to their milk.

Studies were conducted to establish whether this inefficiency was caused by small limitation in the ability of the mammary gland to transfer α-tocopherol. On day 2 after single intraperitoneal injections of 5 or 10 g of DL-α-tocopherol as an emulsion, vitamin E content of milk fat increased from about 20 to 62 and 141 μg/g, respectively. Daily dietary supplementation of vitamin E supplied as DL-α-tocopherol at 400 g/t dry matter showed that the response depended upon the energy status of cows. When started at week 4 of lactation, when cows were losing body tissue, the supplementation, which provided 8–10 g/day, increased vitamin E content of milk fat from about 10 to 25 μg/g within 1 week and at the end of 4 weeks reached about 40 μg/g. The same supplementation started at weeks 9, 14, 15, or 16 of lactation resulted in levels of vitamin E in the milk fat of 45–51 μg/g within 1 week.

It seems that the mammary gland is capable of transferring large amounts of vitamin E to milk and the inefficiency in the utilization of dietary vitamin E results from mobilization of adipose tissue fat and transformation of vitamin E in other tissues such as the liver.

Protein quality of alfalfa silage

Alfalfa is of high nutritive value, however ensiling reduces protein quality through a combined effect of plant enzyme action and microbial activity. Plant enzyme activity, in particular proteolysis, serves no useful purpose and can degrade up to 60% of the true protein to nonprotein nitrogen.

In a series of experiments plant protease activity was inhibited using heat, applied at 90°C for 2 min just after the crop was cut. Three silage pairs, each comprising a control and a heat-treated silage were studied. Silages within each pair were prepared from the same crop and were of similar dry-matter content. Heat-treatment reduced the extent of protein breakdown by up to 50%.

The silages were fed to sheep with rumen and duodenal cannulas to evaluate digestion. Heat-treatment reduced the concentration of rumen ammonia and increased the amount of nonammonia nitrogen (NAN)—a measure of amino-acid nitrogen, passing from the rumen to the intestines. The response in NAN passage varied between 10 and 25%. Increased flow of NAN to the intestines resulted from reduced degradation of dietary protein in the rumen and from increased efficiency of microbial protein synthesis. Heat-treatment had no negative effects on the absorption of nitrogen in the intestines, as can occur in heat-damaged silages.

In a feeding trial comparing one silage pair using young lambs, heat-treatment increased voluntary intake by 40% and the daily rate of body weight gain from 56 to 145 g. The increased gain was attributed to the direct effects of increased intake and the indirect effects of improved protein quality. The

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experiments showed that short-term heat-treatment inhibited the negative effects of plant proteolysis on the quality of silage protein. The results demonstrated that the extent of proteolysis in silage had a direct influence on the utilization of crude protein and voluntary intake of alfalfa silage in sheep.

Fiber degradation by rumen bacteria

Rumen bacteria have enzymes capable of hydrolyzing (1,3)-, (1,4)-, and (1,3)(1,4)-β-D-linkages between glucose units. An enzyme specific for (1,3)(1,4)-β-D-glucans was previously cloned into *E. coli* and purified. An enzyme that hydrolyses (1,3)-β-D-linkages is also present in rumen bacteria. This enzyme has been purified from the culture fluid of *Ruminococcus flavefaciens* grown on cellulose. A hundredfold purification has been achieved using anion exchange and hydoxylapatite chromatography. The enzyme has a pH optimum of 7.5–7.0 and a temperature optimum of 55°C. The molecular mass of the enzyme is in the range 90–100 kilodaltons and the k_m of the enzyme for its substrate, laminarin, is approximately 0.3 mg/mL. The products from hydrolysis of laminarin, which could be identified, are glucose and gentiobiose. Five or six other products were also present but could not be identified readily. They are probably oligosaccharides of glucose units containing both (1,3) and (1,6) linkages. Activity of the enzyme with laminarin as substrate has been compared with other (1,3)-β-D-glucans such as curdlan, carboxymethylpachyman, and scleroglucan.

Methane biosynthesis

Methane synthesizing bacteria were shown to require Na^+ for the production of adenosine triphosphate (ATP) and methane. The site of action of Na^+ is not known but it appears to function in a Na^+/H^+ antiporter, whereby H^+ expulsion from the bacterial cell is accompanied by Na^+ import. Because monensin functions as a Na^+/H^+ antiporter in membranes, low levels of monensin have been shown to stimulate methane and ATP synthesis although at higher levels monensin is a powerful inhibitor. Work is in progress to establish optimum Na^+ levels in the rumen for maximum ATP production.

The complete structure of the cytoplasmic cofactor, which regulates methane synthesis in rumen bacteria, has been characterized. The intact molecule consists of uridine diphosphate linked through two sugar residues to 7-mercaptoheptanoylthreonine phosphate. This cofactor is an absolute requirement in the biosynthesis of methane and its activity cannot be replaced by any other known cofactor.

SHEEP PRODUCTION

Development of specialized sire and dam strains

The three synthetic strains of sheep developed through selection from crossbred foundations have been recognized as new breeds under the *Livestock Pedigree Act*. The Canadian ARCOTT breed (ARC Strain 1) developed for use as a terminal sire has a superior growth rate and lean meat yield. The Outaouais ARCOTT (ARC Strain 2) and Rideau ARCOTT (ARC Strain 3) breeds, developed for use as prolific dam breeds, have an average litter size of 2.5–2.6. Foundation stocks have been selected and registered by the Canadian Livestock Records Corporation on behalf of the Canadian Sheep Breeders Association (CSBA), which has been given responsibility for them.

To preserve the germplasm resources of the breeds, the first nucleus flocks of registered animals have been established at selected locations across Canada. When establishment of the nucleus flocks has been completed, about 400 registered ewes and 40 registered rams of each breed will have been allocated. Typically, nucleus flocks consist of 40 ewes and 3 rams.

A preliminary study has evaluated the growth performance of purebred and crossbred lambs of the ARCOTT breeds under management conditions typical of those prevailing in the Canadian sheep industry. Body weights of lambs from reciprocal matings of the Outaouais ARCOTT and Rideau ARCOTT breeds were, on average, 0.2 kg heavier at 91 days of age than their purebred contemporaries. In turn, purebred ARCOTT lambs were 4 kg heavier than lambs of the Finnish Landrace breed, which is being maintained as a random-bred control. Lambs of a three-breed cross, produced by mating crossbred ewes of the ARCOTT dam breeds with rams of the Canadian ARCOTT and Suffolk (a random-bred control) breeds, were 2.2 kg heavier at 91 days of age than lambs of the purebred or crossbred ARCOTT dam breeds. Also, lambs sired by Canadian ARCOTT rams were generally heavier than those sired by Suffolk rams.

Reproductive physiology

Follicular growth and ovulation. The presence and localization of relaxin (RLX) in luteal tissue during the estrous cycle has been studied by a comprehensive immunocytochemical examination of porcine ovarian tissue obtained from gilts induced to ovulate by treatment with pregnant mares' serum gonadotropin and human chorionic gonadotropin. Ovaries were obtained at laparotomy during the periovulatory period and at specified times through day 19 postovulation. Emphasis was placed on obtaining tissue at intervals of 12–24 h up to 96 h after ovulation. RLX immunostaining was evident in theca interna cells before and at 6 h after ovulation. At 18 h after ovulation, RLX immunostaining, comparable to that seen in theca interna cells, was observed for the first time in luteinizing granulosa cells. As luteinization progressed it became difficult to identify the origin of the RLX immunostaining cells. However, the intensity of RLX immunostaining increased with corpus luteum development, with the staining becoming localized in the large luteal cells. By day 19 after ovulation RLX immunostaining was undetectable. These results indicated RLX was present in the corpus luteum during its formation and functional lifespan. Also, it appeared that the presence of RLX in granulosa cells postovulation was associated with cell luteinization.

Manipulation of photoperiod. Age at puberty and reproductive performance was determined for ewe lambs of the synthetic sire and dam strains raised under different photoregimes. The lambs were bred during January, May, or September at 30–32 weeks of age. Irrespective of birth date, the lambs were reared under continuous light from birth to 5 weeks of age. From 5 to 20 weeks they were kept under 16 h light daily (16L:8D; treatment A), 8 h light daily (8L:16D; treatment B), or a split photoperiod of 8 h total light daily (7L:9D:1L:7D; treatment C). Subsequently, all lambs were exposed to 9 h light daily until after breeding. The incidence of puberty at 28 weeks of age was similar (~50%) for lambs reared under treatments A and C and higher than that of lambs raised under treatment B. The reproductive performance of the lambs bred after treatment with intravaginal sponges impregnated with fluorogestone acetate and pregnant mares' serum gonadotropin to induce a synchronized estrus was not influenced by the previous photoperiod history or by sexual maturity at the start of the sponge treatment. However, strain, age, and weight of lambs at breeding influenced significantly the reproductive outcome.

POULTRY BREEDING

Broiler meat production

In recent decades, broiler breeders' flocks have been selected intensively for greater body weight at younger and younger ages. In addition to large increases in growth rate, there have been correlated increases in fatness, especially abdominal fatness. Genetic parameters for body weight, feed efficiency, and abdominal fatness have been estimated using six generations of data from selected and control lines of the broiler sire and dam populations at ARC. Genetic correlations revealed feed efficiency to have higher, positive correlations with gains at 4–6 weeks than with either 4- or 6-week body weights. In fact, correlations between feed efficiency and 4-week weight were negative. In addition, 4-week weight had a higher correlation with abdominal fatness than carcass weight. Hence, selection for very young body weights should be avoided to prevent correlated increases in abdominal fatness and reductions in feed efficiency. It was concluded that breeders should select for weight gain during the latter half of broiler growth unless they include selection for feed efficiency or low abdominal fatness with body weight, or both.

Five generations of selection in broiler dam lines for weight at 28 days, feed efficiency at 28–42 days, and hatching egg production to 40 weeks revealed heritabilities of 0.32 for 28-day weight and 0.14 for feed efficiency at 28–42 days. Corresponding estimates based on sire variance components were 0.38 and 0.16. Correction of feed efficiency for differences in body weight at the beginning of the test period increased heritability to 0.20. This increase indicated that the response to selection for weight-corrected feed efficiency could improve the response to selection by as much as 25%. For broiler breeders that are now being selected for feed efficiency, this simple adjustment could make major increases in expected genetic gains.

Vitamin D_3 and eggshell quality

A previous study examined substitution of various D_3 metabolites for D_3 itself in a laying ration. 1,25-Dihydroxyvitamin D_3 [1,25-$(OH)_2D_3$] at a level in the feed of 5 µg/kg was most effective in improving eggshell quality when fed to hens from 59 to 80 weeks of age. Further research indicated that 1,25-$(OH)_2D_3$ at levels of 3, 5, or 7 µg/kg had no significant influence on plasma calcium, jejunal or uterine ATPase, or uterine carbonic anhydrase compared to control rations containing D_3. When the metabolite 24,25-dihydroxyvitamin D_3 was added alone (5 µg/kg) or in combination with 1,25-$(OH)_2D_3$ (each at 5 µg/kg), uterine ATPase was depressed significantly compared with the control. It was concluded that the beneficial effect of 1,25-$(OH)_2D_3$ on eggshell quality must be through other physiological factors.

Goose management and genetics

Artificial insemination of geese is greatly dependent on the persistence of high-quality semen production. In a study of two strains of Embden ganders, late in the breeding season (29 May–30 June), semen quality of those maintained indoors under 10 h light and 14 h darkness (10L:14D) was compared with those kept outdoors under natural light, estimated at 15L:9D. No significant differences were found between strains for semen traits. Semen quality was generally low in that only 18.8 and 7.5% of ejaculates from ganders kept indoors and outdoors, respectively, were potentially useful for artificial insemination. Concentration and yield of spermatozoa and percentage of mature spermatozoa were all significantly greater in ejaculates of ganders kept indoors compared with those kept outdoors. It was concluded that the indoor light environment was better than that outdoors for producing good-quality semen.

Medium to high heritabilities of fatness traits suggest that selection against such traits could result in leaner carcasses. To avoid the costly procedure of killing siblings to assess fatness of potential breeders, plasma traits were investigated to determine if they could be used to evaluate fatness in the live bird. Heritabilities of the plasma traits, very low density lipoproteins, redox potential, and pH were quite high (≥ 0.44), indicating that these traits could be changed. However, phenotypic correlations between these plasma traits and intestinal fat, leaf fat, their sum, and skin plus fat, expressed as weight or as a percentage of carcass, were low (≤ 0.25). Therefore, under the conditions of this study, these traits could not replace testing of siblings to select for reduced fatness.

Poultry egg production

As yet there is no proven, satisfactory scientific method to combine all the information available to determine the breeding value of a layer. The most promising method at present is best linear unbiased predictions (BLUP). Procedures were developed to calculate BLUP breeding values for quadratic characters of related layers on a continuous basis in a production environment. A profit function for economic evaluation and selection of layers was revised, extended, and generalized. The profit function allows improved assessment of poultry flocks for management and selection and will allow researchers and economists to refine analyses for the poultry industry. A subset of this function was used with breeding values estimated by BLUP to evaluate overall merit.

Fear in poultry is a natural adaptive behavior, but too much fear can lead to economic loss and lower welfare. A study of environmental enrichment in layers, conducted in cooperation with the Nova Scotia Agricultural College, Truro, and the Institute of Animal Genetics and Physiology, Edinburgh, revealed strain differences in fear levels as measured by tonic immobility and open field tests.

Disease resistance genetics

Infection with lymphoid leukosis virus (LLV) is an industry-wide problem and economic losses from LLV are high. Recently, virulent field strains of LLV that result in high mortality as well as the more usual subclinical infections have been reported. Eradication can be achieved at the breeder level, which will improve the accuracy of selection for egg production. Many strains of chickens have been free of LLV for several generations, but some strains resist all effort at eradication.

In poultry populations at ARC, females from a 1986 hatch with readings for the group specific antigen (*gsa*) of LLV in egg albumen above 0.40 were not used as breeders. Sampling was done at about 200 and 360 days. In the 1987 hatch their female offspring were sampled twice for *gsa* in featherpulp between

hatch and 12 days of age, and again between 22 and 31 days of age. Chicks presumed positive were removed and disposed of (~1460 chicks). About 200 chicks from this group were sent to Animal Diseases Research Institute for virus neutralization tests to determine the relationship between ELISA *gsa* level and LLV infection. ELISA *gsa* readings of featherpulp samples ranged from >0.00 to 3.30 with half of the females being 0.40 or higher. The readings are much higher than expected; some of them may result from endogenous viral DNA genes.

To determine the disease status of the flock, an antibody profile using blood serum from a sample of 10 pullets from the middle tier of each rearing cage unit, post 14 weeks of age, was taken in November 1987. After housing, egg albumen was sampled from one egg of each hen and tested for LLV *gsa*. The incidence of shedders did not decrease appreciably although the incidence of hens in the classes 1.60 and above was reduced. Little relationship was found between LLV *gsa* in featherpulp of chicks and either LLV antibody or LLV *gsa* in egg albumen. Also, there was little correspondence between hens testing positive for antibody and those testing positive for LLV *gsa* in egg albumen. Five of about 1600 hens sampled for antibody were test-positive for both LLV antibody and LLV *gsa* in egg albumen.

SWINE PRODUCTION

Swine behavior

Farrowing crates restrict the movement of the sow during the birth process and lactation and thus help to reduce accidental crushing of piglets by the sow. However, close confinement is controversial in terms of animal welfare and may contribute to farrowing difficulties under some circumstances. A new design of farrowing crate was developed with sides spaced well apart (1.15 m) at the sow's standing height but angled inward near the floor. The design allows sows to move freely and turn when standing, but restricts their resting area and prevents sows from dropping suddenly onto one side. Survival and body-weight data were collected for 20 farrowings in the prototype crate and for 18–20 farrowings in each of three other crate types. No significant differences were found in stillbirth rate, other deaths to 14 days, or average piglet weight gains, but gains were somewhat more variable in one of the conventional designs that interfered with the piglets' access to the teats. The principle of inward-sloping crate sides may provide a less restrictive alternative to conventional farrowing crates, but large-scale testing is needed.

Traditionally it has been assumed that piglets raised by the sow have no need for drinking water during the first days after birth. Doubtless this is true of healthy piglets receiving adequate milk, but many newborns experience some degree of milk deprivation. Use of drinking water by piglets was determined for 51 litters by weighing and refilling a bowl-type water dispenser each day for the first 4 days after farrowing. Piglets drank an average of 46 g/day per piglet over the 4 days, but there was great variation from litter to litter. Litters that lost weight or gained very little on days 1 and 2 drank considerable water, averaging about 110 g/day per piglet on day 2. Litters with high initial weight gains drank little water during this period. The results suggest that piglets will drink appreciable amounts of water on the first days after birth, especially if their milk intake is limited. Under these circumstances water intake may help to prevent dehydration and promote survival of piglets with low early milk intake.

Naked oats

Naked oats (*Avena nuda*) differ from common oats (*Avena sativa*) in that the hull is loosely attached and is blown away by combining when harvested. Naked oats have low fibre, high protein, and high oil contents. When naked oats were fed as a replacement for corn and soybean meal in diets for growing–finishing boars and barrows, a supplement of lysine improved growth and carcass quality. Boars ate less feed daily then barrows; the rate of gain for boars was lower but feed efficiency was better than for barrows. The study supported the inclusion of at least 48% naked oats in a diet for growing–finishing pigs.

Carcass quality

ARC research, partly funded under the Ontario pork industry improvement program, continued to study environmental factors that can affect the incidence of pale, soft, exudative (PSE) pork under field conditions. Current research determined the influences of packing plant conditions on the incidence of PSE. The study was made possible by the active cooperation of the industry.

ANIMAL WASTE UTILIZATION

Pesticide persistence and movement

In a 14-ha corn field, concentrations of metolachlor, cyanazine, and atrazine were essentially nondetectable in clay loam soil at depths of >0.3 m. Metolachlor was detected in effluent from 0.6 to 1.0 m deep tiles only after an intense rainstorm event 50 days after application but not at other times, suggesting possible transport to tile drains via soil macropores. Cyanazine was not detected in tile effluent but atrazine was detectable most of the time. Atrazine was not detected in the tile effluent from a 4-ha corn field with similar soil type 4 years after the last application of the herbicide.

Composting of liquid manures

In a collaborative study with the Land Resource Research Centre, acidic, hydrophillic sphagnum peat of low bulk density and ion-buffering capacity was composted with manure slurries from dairy cattle, sheep, and poultry. Nonmechanical aeration was provided by laying the compost heaps on open-ended, horizontal, perforated plastic pipes. An envelope of peat around the compost mixture restricted ammonia and odor release. Compost pile temperatures of 45 and 55°C were attained in 1 and 4 days, respectively. Temperatures between 45 and 65°C were maintained for 22, 14, and 36 days in the dairy cattle, sheep, and poultry manure compost mixtures, respectively. The total time for composting from laying of heaps, heating, and cooling to ambient temperatures varied from 43 to 48 days. The nitrogen content of the finished composts varied from 1.6 to 1.8% and the carbon:nitrogen ratio ranged from 16 to 23.

POULTRY NUTRITION

Broiler breeder management

Development of broiler breeders during the period of transition from pullet to layer is important to their ability to produce hatching eggs. Replacement of white light by narrow-band green light during weeks 8–20 decreased mortality by 28% during the transition period and up to 45 weeks of age. The age at first egg was delayed for broiler breeders given a relatively low level of feed intake during the pullet–layer transition. This disadvantage was offset by 2% more hatched chicks per hen, resulting from 1.6% higher peak level of egg production and 3.9% higher fertility of eggs laid.

Naked oats

Naked oats, a cereal feedstuff of relatively high true metabolizable energy (17 MJ/kg) and content of crude protein (180 g/kg), was shown previously to give satisfactory growth and feed efficiency when incorporated in a broiler grower diet at a level of 400 g, a cereal feedstuff of relatively high true metabolizable energy (17 MJ/kg) and content of crude protein (180 g/kg), was shown previously to give satisfactory growth and feed efficiency when incorporated in a broiler grower diet at a level of 400 g/kg. However, naked oats depressed growth when fed at 200 g/kg to broiler starter chicks from hatching to 4 weeks of age. Oat β-glucan was identified as a cause of reduced weight gains and feed efficiency in young chicks. When the dietary level of β-glucan was increased from 42 to 81 g/kg, bioavailabilities of energy, ether extract, and individual amino acids were decreased by 10, 5, and as much as 8%, respectively. Lysine and threonine were the amino acids affected to the greatest extent. The causative agent, β-glucan, appeared to act by modifying the intestinal environment and microflora such that the emulsification and absorption of lipids, together with fat-soluble vitamins, was impaired. The resulting decrease in nutrient availability, combined with a lower feed consumption because of an adverse intestinal environment, decreased weight gains in chicks.

Supplementation of a broiler starter diet containing naked oats at 600 g/kg with factorial combinations of bile salts, fat-soluble vitamins, and antibiotic demonstrated that the growth-depressing factor influenced the intestinal ecology of chicks. This finding supported the observation that fat absorption was a limiting factor to chick growth. When broiler chicks at 1–3 weeks of age were fed diets of naked oats supplemented with both neomycin and a premix of vitamins A, D_3, E, and K, the chicks gained weight equal to that obtained with a corn–soy control diet. An attempt to replace the antibiotic by a *Lactobacillus–Streptococcus* probiotic, as an ameliorator of growth depression induced by the naked oats, was not successful.

Feedingstuff evaluation

Application of the true metabolizable energy system for evaluating feedingstuffs was extended by a joint project with the National Institute of Animal Science, Denmark. Samples of 84 feedingstuffs, previously assayed for apparent metabolizable energy (AME_n) using pigs, were assayed for true metabolizable energy (TME_n) using adult cockerels. The results show that the amount of energy that is available to a pig can be predicted from the TME_n value of the feedingstuff as determined with cockerels. The prediction is improved ($P < 0.05$) when crude fiber is included in the model. Several prediction equations were developed for various classes of materials. Extensive banks of TME_n data, determined via the cockerel assay, can now be used to establish comparable information for use by swine nutritionists. The cockerel assay can be completed in a few days using a small sample whereas a pig assay takes several weeks, requires much more test material, and costs 20–30 times as much. Preliminary results indicate that similar predictions may be possible for bioavailable amino acids.

ANIMAL FEED SAFETY

Perinatal metabolism

Maternal and fetal blood plasma samples were analyzed to help determine the movement of maternal fat stores to the developing fetus. High levels of n-3 and n-6 essential fatty acids were found in sow's blood throughout gestation and the level of these particular fatty acids reflected the composition of the sow's diet.

The presence of long-chain, polyunsaturated fatty acids in blood plasma indicated that the fetus was capable of chain elongation and desaturation.

Feeding trials were carried out in cooperation with the Food Research Centre and Carleton University to test the use of Jerusalem artichoke flour in milk replacer for piglets. Initial experiments indicated that Jerusalem artichoke reduced diarrhea in young animals but improvements needed to be made with respect to the sensory qualities of the flour.

3-Phenoxybenzaldehyde (3-PBald)

The metabolism of 3-PBald, a primary metabolite of a large number of synthetic pyrethroids, was investigated in laying hens with ^{14}C-benzyl-labeled material. Approximately 98% of the administered dose was eliminated from the body within 24 h after dosing. About 84% of the excreted ^{14}C was extractable with methanol. The methanol extract contained both free and conjugated metabolites; major free metabolites were 3-hydroxybenzoic acid and 3-phenoxybenzoic acid. The polar metabolites when hydrolyzed with enzymes (β-glucuronidase, sulfatase), mild acid (buffer, pH 4.5), and 2 *N* HCl at 80–90°C for 3 h also produced 3-hydroxybenzoic acid; but a considerably larger amount was produced with 2 *N* HCl. 3-Hydroxybenzoic acid was also found in the acid hydrolysate of the methanol extract of excreta from poultry fed either deltamethrin or fenvalerate. 4-Hydroxybenzoic acid was identified as a natural constituent of chicken excreta. Formation of 3-hydroxybenzoic acid is an example of a unique cleavage path for diphenyl ether not known to occur in animal and avian species. The data also indicated that 3-hydroxybenzoic acid reacts with other endogenous substances more rapidly than it forms glucuronides or sulfates. The mechanism of ether cleavage is not understood. Further studies are in progress to determine the nature of intermediary compounds leading to the diphenyl ether cleavage.

Mycotoxins

An evaluation of the toxicities of various mycotoxins using a chick embryo toxicity (CHEST) assay has shown a high correlation between this bioassay and that of mouse LD_{50} values obtained from published information. This further promotes the CHEST assay as one possible method that can be used as an alternative to small laboratory animals for toxicity testing. The assay is also being used to support chromatographic methods for the isolation and identification of new mycotoxins.

When livestock and poultry are fed moldy feedstuffs, interest is aroused as to whether toxic residues are transmitted to animal-derived food products intended for human consumption. Studies to date continue to show that neither deoxynivalenol (DON) nor zearalenone (ZEN) residues occur in such products following typical levels of exposure. A long-term study in which laying hens were fed a DON-contaminated diet for 65 days showed no residual accumulation of any concern in eggs. Over 21 days, unnaturally high amounts of

ZEN were added to the feed of dairy cows, with negligible levels of residues being detected in the milk. Studies have been initiated to determine the mechanism of the feed refusal and emetic action associated with DON consumption. Preliminary results indicated that many of the pharmacological effects were directly at the central nervous system level, which suggested that removal or destruction of the toxin in the grain prior to consumption would probably be the most practical approach.

Canola oil

Further studies evaluated the nutritional and toxicological properties of canola oil in newborn piglets. These studies will provide the scientific evidence needed to justify the removal of the U.S. Food and Drug Administration's restriction on the use of canola oil in infant formulas. Piglets were fed artificial milk replacer with canola–rapeseed oil mixtures containing either 2, 5, 10, or 20% erucic acid or soybean oil. No differences were found in growth and digestibility. Only the 20% erucic acid diet showed evidence of myocardial lipidosis, which suggests that canola oil with <2% erucic acid is safe and nutritious. Perfused piglet hearts metabolized either glucose or fatty acids. Optimum work output of the heart was achieved by a combination of glucose and physiological concentration (0.1 mM) of either palmitic or erucic acid. The oxidation rates of both fatty acids were similar, indicating no uncoupling, which was also demonstrated by ^{31}P-NMR measurements.

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INTRODUCTION

The Biosystematics Research Centre (BRC) provides Agriculture Canada, other departments and agencies, and their clients with a unique centre of systematic expertise for dealing with economic and social problems relating to insects, mites, spiders, plant parasitic nematodes, weeds, crop plants, native plants, and plant parasitic and biodegrading fungi. BRC provides Canadians with an expert team of scientists and technicians that maintains and updates an information system ensuring that the identities of any of these organisms can be determined accurately, and that appropriate data on their biology and impact are available quickly. It is a vehicle for the flow of biosystematic information nationally and between Canada and other countries.

BRC develops and maintains primary reference collections of living or preserved organisms to document their identity, variability, and distribution and draws upon unique genetic capabilities for industrial applications. BRC also assists biologists in the agri-food, forestry, environment, and health sectors in evaluating these organisms either as potential crops, pests, agents of biological control, and indicators of environmental quality; or as source of production for mycotoxins, mycorrhizal inoculums, and metabolites; or for use in biotransformations and in food production.

Reprints of publications and copies of this report are available from the Director, Biosystematics Research Centre, Research Branch, Agriculture Canada, Ottawa, Ont. K1A 0C6; Tel. (613) 996-1665.

Robert Trottier
Director

NATIONAL IDENTIFICATION SERVICE

From 1550 shipments of material, 96 608 identifications were made during 1988 on insects, mites, spiders, nematodes, vascular plants, and fungi. Of these identifications, 70% benefited the agri-food sector. The major clients of the service were Canadian universities followed by the Canadian Forestry Service and Agriculture Canada.

Insects, mites, spiders, and nematodes

During 1988, 84 396 specimens were identified of which 36% were for Canadian universities and 15% for the Canadian Forestry Service. Research Branch projects supported by the National Identification Service included: economic insect survey (St. John's); vegetable, berry, and field-crop insect research (Kentville); integrated pest management of apple pests, plus studies on insect pests of blueberries and tomatoes (Saint-Jean-sur-Richelieu); biology of onion maggot parasitoids and predators (London); fruit pest management and biological control of apple pests (Vineland); thrips on greenhouse cucumbers (Harrow); cutworm ecology, plus control of insects and mites in stored products (Winnipeg); biological control of weeds, pests of Saskatoon berries (Regina); control of forage crop insect pests (Saskatoon); biology and control of Russian wheat aphid, as well as insects of cereal crops (Lethbridge); aphids of British Columbia, plus survey of blueberry crops (Vancouver); and biocontrol of thrips on apple trees in commercial orchards, and nonchemical control of leaf rollers on apples (Summerland, B.C.).

Forestry projects were also supported as follows: forest insect and disease surveys (St. John's, Fredericton, Sainte-Foy, Sault Ste. Marie, Edmonton, and Victoria) and revisions to pest catalog listing; new methods of repression of forest insects (Sainte-Foy); plantation pest management and environmental impact studies (Sault Ste. Marie); biology of ash bark beetles (Edmonton); and spruce weevil biological control (Victoria). Plant Protection Division (Food Production and Inspection Branch) submitted specimens for identification from surveys of soybean cyst, blueberry maggot, and Oriental fruit moth, as well as from import and export inspections and certifications.

Examples of provincial government projects assisted were as follows: survey of aphids on barley and winter wheat (Ontario Ministry of Agriculture and Food); studies on wireworms in potatoes (New Brunswick Department of Agriculture); and control of greenhouse

vegetable pests (British Columbia Ministry of Agriculture and Food). Identifications were also provided to various universities: material relating to forensic entomology (Simon Fraser University); arthropod fauna of the Yukon (University of British Columbia); associates of mountain pine beetles (University of Alberta); distribution of lyme disease tick in Ontario (University of Guelph); distribution of *Chrysalina* spp. (Coleoptera) in eastern Ontario, 18 years after initial release (University of Ottawa); and hosts for parasities of eastern spruce budworm (University of New Brunswick). A significant number of inquiries was also received from district health units and dermatologists, for identification of insects in health-related problems.

Vascular plants

During 1988, 7886 collections of vascular plants were identified. The major users of the service were provincial departments (25%), Canadian universities (22%), and Agriculture Canada (20%). The identifications provided for the research stations were associated with the following projects: pollen studies associated with habits of honeybees and cutworm adults, and berry crop investigations (Kentville); weed problems (Charlottetown); drought-resistant fodder crops (Swift Current); and new weed problems and controls, as well as verification of entire reference collection (Regina). Assistance was provided to the Canadian Forestry Service for a study of plants in disturbed peat (Sault Ste. Marie), and Food Production and Inspection Branch divisions were provided with information and identifications related to import and export inspections and certifications for plant protection, and with identification of various seed lots for laboratory services.

Provincial governments were assisted with the following projects: forage productivity and range studies (Yukon Renewable Resources); samples relating to livestock mortality (Alberta); weed control (Manitoba); ecological studies (Ontario Ministry of Natural Resources); and identification of crop weeds (Ontario Ministry of Agriculture and Food and Quebec Ministry of Agriculture, Fisheries and Food).

A significant number of inquiries was also received from the Poison Control Centre for the identification of plants suspected of being poisonous.

Fungi

BRC identified a total of 4326 collections and cultures of fungi during 1988. Major users of the service were the Canadian Forestry Service (59%), followed by the general public (22%). The Research Branch was supported in the following projects: diseases of cereals (Charlottetown); tree fruit diseases (Kentville); diseases of forage legumes (Sainte-Foy); tree fruit root rots (Harrow); diseases of ginseng (Delhi); etiology, epidemiology, and genetics of facultative fungi attacking barley, plus mycotoxin production experiments (Winnipeg); foliar diseases of winter wheat (Saskatoon); biological control of weeds (Regina); and effect of glyphosate on fungal flora, plus diseases of fruit trees (Summerland). The Canadian Forestry Service was assisted with the following: forest insect and disease surveys (Fredericton, Sault Ste. Marie, and Victoria), plus revisions to pest catalog listing; needle blight of eastern white cedar (St. John's); and regeneration pests (Victoria). Food Production and Inspection Branch was assisted with fungal problems relating to nursery surveys, import interceptions, export certification, the death of pigeons at the Central Experimental Farm (Plant Protection Division); and the investigation of a virulent form of blackleg in rapeseed (Laboratory Services Division).

Provincial government projects were supported as follows: livestock mortality cases (Newfoundland Agriculture); diseases of vegetable and fruit crops (Quebec Ministry of Agriculture, Fisheries and Food); diseases of red pine (Ontario Ministry of Natural Resources); and diseases of carrots in storage (Manitoba Agriculture). The Pest Diagnostic Centre (University of Guelph) was assisted with various problems relating to diseases of vegetable and fruit crops. Inquiries were received from poison control centres in Ottawa and Vancouver, and from other provincial health laboratories and hospitals, for the identification of mushrooms suspected of being poisonous.

RESEARCH AND COLLECTIONS

Soil and water organisms

Scientists in the soil and water organisms project conduct systematic research on insect and mite decomposers, predators, and parasites

that constitute the major component of the arthropod communities characteristic of soil and aquatic habitats.

Among activities completed in 1988 were studies on a new species of the soil mite genus *Antennoseius*, unique in having two forms of adult females; a synthesis of the life history and behavior of four species of *Lasioseius* found in grasslands; and a major world revision of the rove beetle genus *Gabrius*, including taxonomy, bionomic, and distribution data for 42 species. These mites and beetles are predators and thus are at the top of the food chain in soil. They are not only potentially important in biocontrol but also are excellent indicators of environmental conditions. Other research on predators included a revision of mites of the genus *Mucroseius*, associated with wood-boring beetles and the economically important pine wilt nematode.

A handbook on beetles associated with stored products in Canada has been submitted for publication. In addition to a taxonomic treatment this handbook includes information on dimorphism, distribution, and the economic importance of 120 species. A technical publication on the wheat blossom midge, *Sitodiplosis mosellana*, was completed. It summarizes all previous work on this pest, which was complemented by research on the larval instars of this species. Unambiguous evidence for there being four rather than three larval stages now provides an easy and rapid means of identification for all immature stages.

Revisions were completed on genera of water mites in the families Momoniidae, Athienemanniidae, and Anisitsiellidae, specific to groundwater habitats and important indicators of water quality. A synthesis of current information on holarctic madicolous midges (Chironomidae) was completed. The first taxonomic treatment of *Limnozetes* in North America was submitted. It indicates that species in this genus have a very restricted distribution and, apparently, are highly sensitive to changes in pH. A major revision on the trichopteran genus *Hydrobiosides* was also completed successfully. This genus has a worldwide distribution, and 72 new species were described, along with a zoogeographic treatment of the world fauna.

Substantial progress was made on book chapters on the 80 species of midges and 150 species of oribatid mites of northern Yukon, a guide to the mites of apple orchards, a book on the oribatid genera of North America, a key and diagnosis for all species of *Culicoides* in British Columbia, including known and potential vectors of bluetongue virus, and a treatment of adults and larvae of North American predaceous ground beetles, Pterostichini.

A cooperative program on sustainable agriculture was established with Macdonald College of McGill University with two objectives: first of defining the communities of both pest and beneficial soil fauna associated with sustainable systems; and second, of providing baseline data for an index of the relationship between diversity of soil fauna and soil quality.

Fieldwork by staff members, donations from cooperating researchers, and an important exchange of material with colleagues in the USSR added significant collections of water mites and soil mites and beetles to the National Collection in 1988. This material is extremely important both for research in progress, and for future research, on the identification, distribution, and relationships of species that occur in Canada.

Beneficial insects

Thirty-five collections of beneficial insects were imported from 16 foreign countries by the biocontrol unit. Forty-seven shipments of live parasites and predators were distributed to 10 Canadian research establishments for laboratory testing or release against the apple maggot, apple ermine moth, Russian wheat aphid, European earwig, mountain pine beetle, spruce budworm, spruce bud moth, gypsy moth, white pine weevil, asparagus beetle, and euonymus scale. Native collections were made of two species of ladybug (Coccinellidae) for programs in Canada and the United States against the Russian wheat aphid, and of a moth species (Lepidoptera) for biocontrol of toadflax. More than 800 copies of the first issue of *Bio-Control News* were distributed. This annual newsletter was prepared with the participation of biocontrol workers and taxonomists across Canada and serves to disseminate information on biocontrol needs, expertise, and programs that influence the setting of research priorities.

A manual on the species of wolf, nurseryweb, and lynx spiders of Canada and Alaska was completed for the series *The insects and arachnids of Canada*. Also completed were major revisions of the world species of

Symmorphus, a genus of predacious eumenine wasps, and of the world genera of two subfamilies of chalcidoid wasps that parasitize mostly wood-boring beetles. Published were major revisions of the New World species of *Alabagrus*, braconid parasitic wasps, and of the North American species of *Gonatocerus*, chalcidoid egg parasites of leafhoppers. The species status of *Agrypon flaveolatum*, an ichneumonid parasitic wasp that had been introduced from Europe to control the winter moth on apple and oak in Nova Scotia and British Columbia, was also clarified, and the species was distinguished from other closely related native species.

Insect pests

Two papers on Cretaceous fossil leafhoppers (Homoptera) were submitted for publication. These papers described 97 species, many well preserved, the unique characteristics of which have profound implications for our understanding of the evolution and relationships of the modern families. The fossil data challenge the validity of the present classification based solely on extant species.

Several papers on the cutworms of the Beringian area in northwestern North America and northeastern Asia were published in 1988. One of these, a zoogeographic analysis of the cutworms of the Beringian area, discusses the significance of this region in the exchange of species between the Old and New Worlds and in determining the composition of the present-day cutworm fauna of Canada.

A catalog of plant parasitic nematodes (order Tylenchida) is in preparation; about one-half of the literature citations have been entered into the data base and checked for accuracy.

The first volume of the *Catalog of the Scolytidae*, the bibliography, was published early in the year. This 685-page book contains more than 21 000 references to the literature pertaining to the scientific study of bark beetles. Part 2, the taxonomic catalog, is well under way. A paper reporting seven new synonymies in the economically important weevil genus *Sitona* and two notes reporting the introduction and establishment of two pest species were published. A revision of *Sitona* should be completed by the end of 1989. The project on the weevils of Canada is progressing; keys to genera in several subfamilies have been completed, and a checklist of all species known to occur in Canada has been compiled. Several new species of *Sitona* have been discovered and several introduced European species have been detected in North America.

Two manuscripts on morphometric studies of aphid complexes on conifers were completed and submitted for publication. A review of the insect fauna of the boreal forest zone of Canada, prepared in cooperation with H.V. Danks (National Museum of Natural Sciences) was completed during the year.

A handbook to the genera and subgenera of sawflies of Canada has been completed, reviewed internally, and submitted for external review.

Collections

The Canadian National Collections of insects, arachnids, and nematodes (CNC) continued to grow through fieldwork of BRC personnel, donations from peers and Canadian public, and exchanges of scientific material with partner organizations, as well as by retentions from the National Identification Service (NIS). The total holdings were increased by acquisition of 262 300 specimens, and the quality of the collection was enhanced by intensive curatorial work involving 310 000 specimens.

The curatorial year 1988 was dominated by two major events, namely by the conducting of the first status report during January–May and by the rearrangement of the collections at the year's end. The status report is based on critical appraisal of entire holdings comprising 1201 cabinets, with 26 782 drawers, 395 985 slides, and 213 131 alcohol vials. Priorized recommendations resulting from the survey were largely implemented, with goals achieved or exceeded. The report provides an historical point from which further growth and development of the CNC could be measured and monitored.

Requests from scientists around the world for the loan of material from the CNC resulted in 196 loans of about 45 000 specimens. The CNC continued to attract specialists from Canada and abroad, and 36 visitors helped to curate its holdings in 1988. CanaColl facilitated 12 of the above visits, with grants both from the endowment and the development funds. The homebound handicapped program contributed significantly in preparation of large amounts of target material accessioned during 1988.

Economic plants

Progress continued in the areas of crop plants, weeds, poisonous plants, native forages, and honey plants. Several scientific papers were prepared clarifying variation in some barley species (*Hordeum*) and on some related cereals. Papers were also written clarifying several wild alfalfa species (*Medicago*), and an identification guide was prepared to the more than 100 species and varieties of this genus. Extensive data on the genus *Brassica* (rape and allies), and on related genera, have been collected into a computerized data base. A new study on Chinese gooseberry, also known as kiwifruit (*Actinidia*), was established in cooperation with Agassiz Research Station. In the area of native forages, several studies were prepared on sedges (*Carex* spp.), common witch grass (*Panicum capillare* L.), blue grass (*Poa* spp.), poverty oat grass (*Danthonia spicata* (L.) Beauv.), and fescue grasses (*Festuca* spp.). Work continued on an atlas of honey plants. In the area of weeds, studies were conducted on velvetleaf (*Abutilon theophrasti* Medic.), ragweed (*Ambrosia* spp.), thistle (*Carduus* spp.), Johnson grass (*Sorghum halepense* (L.) Pers.), proso millet (*Panicum miliaceum* L.), giant foxtail (*Setaria faberi* Herrm.), tansy (*Tanacetum vulgare* L.), spurge (*Euphorbia* spp.), wormwood (*Artemisia* spp.), and mayweed (*Matricaria* spp.). The manuscript was completed for a 200-page manual on Canadian aquatic plants, including weeds of irrigation systems and recreational waters. *Preliminary inventory of Canadian weeds*, a 300-page book, was prepared by four BRC employees. This treats more than 500 of Canada's most important weeds and presents essential data of interest to weed scientists, concerning correct names, distributions, life history, and habitat. Also included is an extensive bibliography for the use of all concerned with the deleterious effect of weeds on the agri-food industry. Progress was made toward a computer information system on poisonous plants of Canada.

Several contributions to the international cooperative publication *Flora North America* and to the international cooperative revision of the *Manual of North American grasses* were initiated. *Plants of Riding Mountain National Park, Manitoba* and *Flore du Parc national du mont Riding, Manitoba*, identification guides with over 300 illustrations, were published in cooperation with the Canadian Parks Service, Environment Canada. The books treat all of the 669 flowering plant species found in the park. They will be of interest to the thousands who visit the park annually and to botanists and conservationists conducting research on the Canadian flora.

The genus Vaccinium in North America, a 200-page illustrated monograph and identification guide to the 26 North American species, was published under contract to Professor S.P. Vander Kloet of Acadia University. Most of Canada's crops are of Old World origin. The genus *Vaccinium* provides Canada with its most important indigenous cultivated crops, the blueberries and cranberries, as well as other plants of pomological, ornamental, and wildlife interest. This publication will be of particular interest to the fruit crop industry and provides essential taxonomic information for plant breeders.

Review articles were prepared on biosystematics and on genetic variation of weeds. Several pilot studies, especially on rape and its allies, were initiated in the new biosystematic laboratory for macromolecular analysis of isoenzymes and DNA and in the new image analysis laboratory. The vascular plant herbarium increased by 8000 well-curated specimens.

Economic fungi

A manuscript was completed on the biogeography of Canadian mushrooms including 70 pages of species distribution maps. Data base files created for the input of records of Canadian mushrooms now include 400 literature references and 7000 mushroom records. The Canadian species *Crinipellis maxima* Smith & Walters was described, and a monograph of the agaric genus *Flammulina* is nearing completion. A paper describing several unusual wood-decaying fungi from North America is in press. In cooperation with staff of Forintek Canada Corporation, a manuscript was prepared on a fungus implicated in lumber decay, and a manuscript on the boreal species of the woodrot genus *Wrightoporia* is nearing completion. Host, distribution, culture, and taxonomic data for a major manuscript dealing with nearly 700 species of the wood-decaying fungi Corticiaceae of North America was accumulated. In cooperation with the universities of Alberta and Maine, a new hyphomycete, *Scytalidium vaccinii* Dalpé, Litton & Sigler, was described, which aggressively forms a mycorrhizal

association with blueberry. A data base III file on the mycorrhizal literature of the past 10 years now comprises more than 120 000 entries on ecto-, endo-, and ecto-endomycorrhizal species. Thirty eight of 57 isolates from soil, representing nine species of mycorrhizal fungi in the genera *Glomus*, *Sclerocystis*, and *Scutellospora* maintained in pure culture, have retained their mycorrhizal capabilities when reinoculated to plant roots. Studies on preserving cultural isolates of mycorrhizal fungi by lyophilization and under liquid nitrogen are being investigated to determine whether mycorrhizal capability is retained under conditions of long-term storage. A manuscript on the genus *Ascosphaera*, responsible for chalkbrood and other diseases of bees was prepared and is now in press. A manuscript on *Phyllosticta* pathogens of conifers was submitted for publication. Two manuscripts on members of the hyphomycete genus *Trichoderma*, which are biocontrol agents for a variety of pathogenic fungi, were completed; two others are nearing completion. Revisions of the ascomycete plant parasitic genera *Diadema* and *Bricookea* occurring in North America and elsewhere were completed. A new major monograph covers 61 species including many plant pathogens in four *Pleospora*-like genera *Clathrospora*, *Platyspora*, *Graphyllium*, and *Comoclathris*. A literature compilation is being prepared of about 1200 described species of the ascomycete genus *Mycosphaerella*, which includes numerous species attacking cultivated plants. The reference, host, distribution, and descriptive data on the species being compiled is currently scattered throughout a vast and often inaccessible literature. In cooperation with staff of the Lethbridge Research Station, new studies on rumen fungi were initiated to support Lethbridge's research aimed at improving feed usage in cattle. A book chapter on the zoosporic fungi, which are important plant viral vectors, will be of immense value in the detection and control of plant virus diseases. An investigation on corn root parasites was conducted in support of the Research Branch's corn research program.

The National Mycological Herbarium grew by 2346 specimens to a total of 254 780. An additional 650 dried specimens were accessioned into the herbarium; 4500 specimens of plant parasitic fungi were donated by the Saskatoon Research Station; and a further 5500 specimens of Manitoba fungi, collected by Dr. G. Bisby and Dr. R. Buller, and 400 specimens, donated by Dr. K. Egger, are currently being filed in the herbarium.

The Canadian Collection of Fungus Cultures grew by 587 isolates to a total of 10 303. The number of requests for cultures increased to 853: Canada (73%), United States (18%), and others (9%). Of these requests, industry accounted for 21%, universities 27%, and government 52%. Of the isolates 70% were sent out to individuals or organizations involved in mycotoxin research and food production. New cryopreservation techniques were devised for the zoosporic fungi and the wood-rotting Basidiomycotina for long-term storage in liquid nitrogen.

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INTRODUCTION

This report summarizes the achievements of the Engineering and Statistical Research Centre (ESRC) in 1988 and lists publications of the staff.

All projects contracted out since 1973 under three engineering programs were completed by 1988, ending an era of this major support to agricultural engineering. In 1973–1974, the development, research, and evaluation of agricultural mechanization (DREAM) program was established. This program was replaced by agricultural engineering research and development (AERD) in 1977–1978 to encompass building and energy research. In 1981, energy research was separated into a program on energy research and development in agriculture and food (ERDAF), and AERD was transferred to the Western Region. Since 1973, the expenditures under the three programs totaled $40 million for 603 contracts with external performers. The results are reported in 513 contract reports. Reports are accessible through the Agriculture Canada library and the Canadian Institute for Scientific and Technical Information (CISTI) at the National Research Council of Canada, where microfiche copies can be purchased. A number of ESRC and Western Region reports also summarize and review the results.

A highlight for the year was the first field trial of an instrumented tractor equipped with a state-of-the-art system for data acquisition. This development has provided a mobile laboratory for the study of tractor–implement–soil interactions in a long-term, multidisciplinary research program on soil conservation and sustainable agriculture.

Peter W. Voisey
Director

ENERGY

An instrumentation and data-logging system was developed for an agricultural tractor to measure tractor–implement–soil interactions. The system was designed as a research tool to be used in research programs on tillage and soil conservation, both at ESRC and in collaboration with other research establishments. It utilizes state-of-the-art components and measures variables such as fuel consumption, implement draft, and soil compaction forces in crop production systems using conventional and conservation tillage.

Measurements, made by transducers mounted on the tractor, are recorded by a microcomputer-based high-speed data logger and are displayed in real time on a computer monitor. A tractor cab extension was built to accommodate the data-logging system and operator.

FOOD PROCESS ENGINEERING

Canadian Patents and Development Limited (CPDL) has filed patent applications in Canada, the United States, and the European Economic Community on the ESRC–Food Research Centre extrusion–microwave puffing process. One company is negotiating with CPDL for a licence to use the process.

Process development is continued on separation technology, thermal processing, freezing, and the use of microwaves. Work on the supercritical extraction process was discontinued in view of industrial developments.

Industrial clients spent time in the laboratory to solve problems in the measurement of food textures. A study on the use of small-angle, oscillatory testing for measuring the properties of pectin gels was completed with the Summerland Research Station.

INSTRUMENTATION AND AUTOMATION

A prototype, microcomputer-based system for analyzing the rheology of dough during mixing was developed to eliminate the need for manual analysis of analog chart records from apparatus that measures the quality of dough. The system was developed in collaboration with the Winnipeg Research Station, where more than 8000 wheat samples from breeders are analyzed annually. The system handles up to four mixographs or farinographs simultaneously. The system is linked with the department's Agrinet computer network so

that results of analyses can be mailed electronically to breeders. A similar system was installed at the Plant Research Centre in Ottawa.

An electronic system for measuring and recording the dimensions of horticultural produce was developed for the Kentville Research Station. The device can obtain two dimensions simultaneously, and the data can be transmitted to a computer for storage and analysis. The system speeds up the measurement of large numbers of samples and reduces errors.

Structural attributes of chaffy seeds such as grasses are a source of variation in obtaining pure seed samples. An electromechanical seed divider was developed to divide chaffy seed samples accurately.

An adjustable-slit, light-scanning system to improve true depth of field in photographic applications was developed for Research Program Service. An adjustable electrode holder was developed for the Plant Research Centre for experiments on cell fusion. Several interfaces for connecting scientific instruments to computer systems were developed to eliminate the need for manual entry of research data.

As part of the continuing study on high-speed, visual detection of cracks and dirt on eggs by machine, a method for detecting blood spots within the egg was conceived.

Electronics repair and maintenance was provided for the Research Branch's scientific equipment in the National Capital Region. Electronics design and microcomputer hardware and software support and consultation was provided within and outside the centre.

STRUCTURES AND MECHANIZATION

Structures

The Canada Plan Service (CPS) design centre issued to provincial contacts 4 plan sets, 11 truss drawings, and 8 leaflets, as instruments of technology transfer for use by farmers, contractors, and builders. Five of the leaflets were bulletin-size works in three series on swine, ventilation, and storage of fruits and vegetables. Many older plans (74 sheets) were re-engineered to conform to the newer, 1984, limit states design, wood code. Advice was provided to six provinces on computer-aided drafting (CAD), promoting system compatibility and the use of the latest technology to facilitate national interchange of technology and efficient work practices.

The *Canadian Farm Buildings Handbook* was completed and published in English and French. This handbook of recommended good practice complements the basic mandatory structural requirements in the Canadian Farm Building Code and the National Building Code of Canada.

Reliability, limit states design, and probability of failure theories were combined to develop a mathematical model to determine the reliability of trusses and similar structures.

Load testing of full-scale frames showed that existing frames with wooden, stud-and-pole knee braces, widely used as wind braces for agricultural buildings, lacked adequate stiffness and factor of safety. Redesigned connections were shown to overcome these deficiencies.

By means of an extensive theoretical analysis, details of construction and connection were developed for using buttresses as a more practical alternative to existing diaphragm technology in wind braces for long (length:width ratio of 3 or more) and high (two or more stories) agricultural buildings.

Laboratory tests of the stiffness and strength of a wide range of farm steel cladding profiles and of fastener properties defined realistic design values for these materials in full-scale ceiling or roof diaphragms for agricultural buildings. The information enables CPS and private sector designers to produce appropriate designs without the need for further full-scale testing.

Collaborative research with Ontario Ministry of Agriculture and Food, at Alfred, defined how to obtain optimum airflow patterns when using natural ventilation in swine buildings. For eastern Ontario, this means orienting barns north–south, locating rooms requiring larger ventilation rates at the predominantly windward end of the building, and adding two windows in the end wall. Also, minimum ridge openings and a control strategy were evaluated for such barns, and a chimney concept was described as an alternative method of ventilation.

Laboratory tests showed satisfactory operation of a continuous baffle and slot inlet, automated by a simple-to-adjust counterweight, for barn ventilation. Adding an interior duct for recirculation reduced cold drafts from incoming fresh air.

In the first 2 days after birth, piglets used twice as much water from dispensers modified to bubble air constantly to the water surface as compared with unmodified dispensers. The bubbling dispenser promotes early use of water by piglets to counteract dehydration when the sow's initial milk supply is low. The research was carried out in collaboration with the Animal Research Centre.

For the soil types tested, in a field experiment, earthern manure storages did not provide effective containment of nitrogen.

Mechanization

A prototype machine for nonselective tying of cauliflower plants at a rate of 45 plants per minute was developed and field tested. The machine is available for agronomic studies and technology transfer. Development of varieties and agronomic practise promise that its economical operation is feasible.

The improved technology developed for a mechanical cucumber harvester has been transferred to industry.

STATISTICAL RESEARCH

Support was provided to all commodity groups by designing experiments, analyzing data, maintaining and enhancing computer software, and conducting research on statistical methodology.

Collaborative work continued on numerous aspects of animal science research. Studies showed that even relatively low levels of the mycotoxin zearalenone in the diet adversely affected conception rates in gilts and reduced the number of piglets per litter. A scheme was developed to enable farm workers on-site to collect samples of both roasted and unroasted corn; roasting was found to reduce mold in the corn substantially without affecting nutrient levels. Research into growth of lambs indicated that relative growth was unaffected by diet, thereby supporting the current procedures for selecting genetic stock. Research on published regression equations relating egg parameters indicated that such equations generally are not applicable among experiments.

Several collaborative studies concerning animal environment were conducted. Compared with natural ventilation, fan ventilation appeared to reduce levels of respirable dust in swine barns. It was demonstrated that meteorological conditions such as barometric pressure and wind affected both the egg production and feed consumption of laying hens.

Investigations continued into methodologies for estimating the bioavailable energy of animal feedingstuffs (i.e., energy that is biologically available to animals and birds). Analyses of data collected by the Animal Research Centre and the National Institute of Animal Science of Denmark indicated that for a wide variety of materials, estimates of bioavailable energy obtained using chickens can be used to predict the energy bioavailable to swine. Use of such predictions will greatly reduce the cost of evaluating swine feedingstuffs and formulating swine rations. Further investigations into the true metabolizable energy bioassay for poultry revealed other factors that affect the accuracy and precision of bioavailable energy estimates.

To support studies on sensory evaluation of food, assistance was provided in the design of several taste panel experiments and the analyses of the resulting data. Areas of investigation included: the effects of breed and sex and various dietary components on the quality of pork; the effects of dietary fishmeal on the sensory properties of chicken; and the effects of breed, sex, age, and diet on the carcass and sensory quality of geese.

Research continued into some statistical aspects of integrated pest management. The binomial sampling scheme was both extended and simplified, enabling a decision regarding whether intervention is required to be easily implemented. A sequential counting scheme for mites has been successfully and widely implemented in orchards throughout British Columbia. A model was developed for the seasonal abundance of *Lygus lineolaris* (Palisot de Beauvois) in strawberries. Based on extensive data collected over several years, an economic threshold was determined for injury to potatoes by the Colorado potato beetle.

New methodology that separates environmental variation into its predictable and unpredictable components was developed for analyzing data on cultivar × location × year. This algorithm enables the identification of

each cultivar's optimum range of locations and the selection of the most stable cultivars. Methods were also developed to classify sites, thereby enabling a reduction in the size of variety trials.

Research continued into automatic procedures for pattern recognition. A dissimilarity vector was developed that eliminates the restrictive assumptions associated with other methods of classification. This methodology was used to distinguish distribution patterns of weeds in northern Alberta. Other procedures were developed and used to identify grasses found in the Canadian high Arctic. Other collaborative research activities with Beaverlodge Research Station found: (*a*) alternating strips of grass and legumes results in a higher content of dry matter in the pasture than that found in a random mixture; (*b*) management practices can reduce the herbicide required to control quack grass; and (*c*) high yields of honey come from colonies in which the worker bees have large wings and femora.

Statisticians advised researchers from more than 40 establishments throughout Canada on various subjects including experimental design, use of computer software, and data interpretation. This facility was used more than 150 times. The computer systems and programming unit responded to more than 60 requests for assistance from branch personnel. A quarterly newsletter was distributed to all branch establishments.

The library of computer software continues to be used about 1000 times per month. The computer system for the eastern cooperative cereal trials was enhanced to handle generalized lattices at the stages both of design and of data analysis. Computer programs and on-line user instructions for analyzing single- and multi-line quantal assays were completed. The maximum likelihood program (MLP) for nonlinear optimization (curve-fitting) was evaluated, and a multi-site license was acquired for the branch. Additions were made to the on-line library of examples for programs and for the SAS and GENSTAT software systems; the scope of this library was expanded to include examples illustrating the use of MLP. A monthly bulletin describing features of, and enhancements to, these systems was distributed to personnel at more than 30 branch establishments.

Computer data bases were constructed for the Industry Relations Office to monitor the licensing of developments in technology, collaborative research agreements, and inbred–hybrid seeds that are licensed. The computer systems and programming unit participated extensively in the development of the data base for the branch's study area.

Twenty-five requests for training in the use of general computer and statistical software from establishments throughout the department were handled. Developed software was distributed to five research–government establishments external to the department.

SUPPORT SERVICES

The data base on engineering research was kept up-to-date, particularly with North American results. Surveys were conducted on research and development of aerial spraying in Canada, and the data base was expanded to cover the topic. A bibliography on research into North American aerial applications was published.

TECHNICAL SERVICES

The shop facilities were improved by retrofitting a number of machine tools with digital read-out systems. This improvement now permits the fabrication of research prototypes to either metric or imperial dimensional standards.

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INTRODUCTION

The role of the Food Research Centre (FRC) is to contribute to the marketability of agri-food products by developing new and enhanced technology in food safety, nutrition, and quality. Through a combination of in-house research, collaborative research projects, and technical advice, the centre's scientists support development of industry and consumer protection. The centre transfers technology to industry and government by means of workshops, seminars, and advisory services. For example, the centre conducts workshops on sensory analysis techniques and dairy product quality and collaborates with Canadian Patents and Development Limited in marketing patented technology. Cost-shared research with companies or industrial associations provides another mechanism that facilitates the development and adoption of new technology.

The centre's staff also contributes significantly to the operation and work of the Canada Committee on Food, the Canola Council of Canada, the National Dairy Council of Canada, the International Dairy Federation, the Codex Alimentarius Commission, and the International Consultative Group on Food Irradiation. In addition, the centre provides advisory services and expertise in evaluation of research proposals for agencies such as the Natural Sciences and Engineering Research Council, the National Research Council of Canada, and the Canadian International Development Agency.

In collaboration with other branches of Agriculture Canada, the centre developed and obtained approval for a nutrition policy that describes the department's role and responsibilities in the nutritional aspects of agri-food products. The Agriculture Canada Nutrition Coordinating Committee was formed under the leadership of Dr. Lloyd.

The scientific and technical contributions of three dairy scientists have been recognized: Dr. Modler received the Dairy Research Foundation Award; Dr. Harwalkar and Dr. Emmons received the Pfizer Award and an Agriculture Canada Merit Award, respectively. Dr. Emmons was elected chairperson of Commission B (Technology and Engineering) of the International Dairy Federation. Dr. Tape was elected vice-chairperson of the Codex Alimentarius Commission and chairperson of the International Consultative Group on Food Irradiation.

This report provides highlights of research activities in 1988. Publications and more information can be obtained by writing to the Director, Food Research Centre, Research Branch, Agriculture Canada, Ottawa, Ont. K1A 0C6; Tel. (613) 995-3722.

N.W. Tape
Director

PROCESSING TECHNOLOGY

Extrusion cooking

The *Research Branch Report 1987* described a process for producing a dense, starch-based, glass-like extrudate, which expands upon subsequent treatment with microwave energy. In 1988, the starch glass was examined for its physicochemical properties. As extrusion temperature increased and moisture content decreased, so too did the indexes for water solubility and water absorption. Wheat starch glasses were examined by gel permeation chromatography on a Sephacryl S-1000 column and were compared with the chromatographic profile for native wheat starch. The high molecular weight amylopectin component was found to decrease as extrusion temperature increased and moisture content decreased. The extent to which each starch glass expanded upon microwave treatment was found to be related inversely to the residual amount of amylopectin component. After storage of the starch glass for 9 months, moisture loss did not exceed 7% by weight in glasses initially assaying 20 and 25% moisture content prior to storage. Prolonged storage had no detrimental influence on microwave expansion.

Oat β-glucans

Complex formation between Calcofluor and β-glucan has been utilized in a flow injection analysis system for analysis of oat β-glucan. Preliminary analyses, in agreement with the literature, show good correlation with values determined enzymatically.

Rapid methods utilizing high-performance liquid chromatography (HPLC) have been developed to characterize physicochemically β-glucans in oat fractions, barley, malt, wheat, and rye. No detectable differences in molecular size or structure of β-glucan were obtained from different cultivars or from different fractions of the oat groat. Barley, wheat, and rye β-glucans differed structurally from oat β-glucan.

Oat gum prepared at the POS pilot plant in Saskatoon was of lower apparent viscosity than a commercial guar gum at 1% w/v and at low shear rates. In glucose tolerance tests carried out in collaboration with Ottawa Civic Hospital, both gums were found to reduce postprandial rises in glucose and insulin similarly and significantly in healthy human subjects. Oat bran (14.5% β-glucan), fed as a porridge to healthy subjects, lowered the postprandial rise in glucose relative to a control group fed cream of wheat. Oat gum, added to cream of wheat to mimic oat bran's β-glucan content, similarly lowered the postprandial rises in glucose and insulin. The results suggest that the β-glucan of oats is a physiologically active component, and that the extracted product, although of reduced molecular size, has a similar activity to the intact cell-wall polysaccharide. These studies were supported by Quaker Oats Company.

Oat phenolics

Naturally occurring phenolic compounds are involved in a wide variety of biochemical and nutritional processes. Despite the widespread use of oats and oat components as feed and food ingredients, little is known about the structure of oat phenolics.

Oat grain phenolics were characterized with particular emphasis on the structural elucidation of bound forms of the commonly reported hydroxycinnamic acids.

The occurrence of a new group of nitrogen-containing constituents, the avenanthramides, reported in 1987, has been established. Two-dimensional, thin-layer chromatography showed that groat extracts contain more than 25 distinct avenanthramides, whereas hull extracts contained about 20. Some 15 were common to both groat and hull preparations. The complete structures of 10 avenanthramides have been elucidated using ^{1}H- and ^{13}C-nuclear magnetic resonance (NMR), mass spectroscopy, ultraviolet absorption spectroscopy, and hydrolytic techniques and confirmed by total synthesis.

The determination by HPLC of these *N*-aroylanthranilic acid alkaloids has been established. A relationship was developed between the observed retention time and the presence of the different functional groups of the molecule, enabling rapid elucidation of potential analogues in complex avenanthramide mixtures.

Oat protein

Acid-hydrolyzed (deamidated) oat protein was used to substitute meat in a wiener formulation. When compared with the all-meat wiener, there were progressive decreases in cook yield and firmness but a slight increase in cohesiveness with increases in the level of substitution. When compared with the unmodified oat protein and three legume proteins, wieners containing acid-hydrolyzed oat protein had significantly better texture.

The cooking profiles (rheology thermograms) of wiener batter substituted with native and acid-hydrolyzed wheat gluten were assessed by small-amplitude, dynamic oscillatory tests. Results show that the changes in mechanical properties (storage modulus, loss modulus, and loss tangent) in the batter during heating were attributed to fat melting and myosin denaturation. Replacement with gluten led to decreases in moduli, indicating a weakening in the structure of the batter.

Fructosans from Jerusalem artichokes

Short-chain, fructo-oligosaccharide (FOS) polymers are claimed to have beneficial properties, e.g., they are noncariogenic and function as dietary fiber. FOS assists in the proliferation of bifidobacteria in the lower gut of animals and humans and results in competitive exclusion of harmful pathogenic and putrefactive bacteria, which do not metabolize FOS.

Jerusalem artichokes (*Helianthus tuberosum*) are an excellent source of fructo-oligosaccharides. Up to 80% of the dry matter in the tubers is FOS. Processes have been developed for the preparation of FOS as a dry, off-white powder with a slight characteristic flavor. A patent application has been filed with the Canadian Patent Office.

A major problem in handling the tubers has been storage. Under ambient temperature and air contact, the tubers readily dessicate and become heavily contaminated with molds.

Washed tubers have, however, been successfully stored for more than 12 months in sealed 6-mil polythene bags (to prevent moisture loss, with lower oxygen and increased CO_2 in the atmosphere) at 4°C.

A collaborative research study was initiated on the nutritional and therapeutic benefits of combinations of FOS and bifidobacteria in feed and food applications.

DAIRY TECHNOLOGY

Multiple-component pricing of milk

A new approach was taken to evaluate various systems of multiple-component pricing of milk. Three formulas for milk pricing were compared for their effect on costs per unit of three classes of milk products from milk of varied composition. The present formula, fat + constant (fat differential), gave uniform costs of fluid milk for milks of varied composition, whereas that formula resulted in different costs of those same milks when used for cheese or for butter and powder manufacture. Similarly, a formula of fat + protein + lactose and minerals was satisfactory for butter and powder type of products yet unsatisfactory for fluid milk and for cheese. A formula based on fat and protein was satisfactory only for cheese. No single formula was satisfactory for all products. However, a blend of the appropriate formulas, depending on quantities of milk used, gave acceptably small differences in costs of milk of varied composition. The differences in milk costs with inappropriate formulas were great enough to affect the profitability of milk plants.

Astringency in milk

The relationship between products of proteolytic breakdown and astringent off-flavor in milk was examined. Pasteurized skim milk was treated with 12 psychrotroph proteinases and the naturally occurring milk proteinase, plasmin, and was evaluated organoleptically for astringency. At comparable levels of digestion (glycine value of 0.5 μm/mL of milk), samples treated with plasmin and only four of the psychrotroph proteinases produced astringency. Chloroform and methanol extracts of astringent samples of skim milk showed typical peaks by fast protein liquid chromatography (FPLC) and characteristically increased levels of γ-casein by urea polyacrylamide gel electrophoresis (urea-PAGE).

The astringent off-flavor has been linked to the production of γ-caseins, which are specific breakdown products of β-casein (cleavage of peptide bond between residues 28–29, 105–106, and 107–108). Further proof of this link was obtained by treating purified β-casein with plasmin, by producing astringent off-flavor, and by demonstrating them to be γ-casein by FPLC and urea-PAGE.

Molecular genetics and physiology of starter cultures

Investigations have continued in the development of genetically engineered starter bacteria for accelerated cheese ripening, improved fermentation, and flavor. In lactic acid bacteria, genetic characteristics of industrial importance have been found to be plasmid-borne. While investigating the stability of proteolytic activity in lactic streptococci, it was discovered that most plasmids are lost spontaneously after extended incubation of bacterial cultures in synthetic media and in milk. This finding led to the development of a simple technique for curing plasmids in lactic streptococci.

Thermophilic lactic streptococci were found to be very sensitive to acid pH, leading to uneven distribution of bacterial population in milk products. This finding was confirmed by a survey of six brands of commercial yogurts. Isolation and characterization of acid-tolerant strains indicated a discrete gene mutation involved in acid tolerance.

Regulation of lipase synthesis in psychrotrophs

Arginine caused transient repression of extracellular lipase secretion by *Pseudomonas fluorescens*. Arginine analogues, which could only partially be metabolized by the microorganism, completely repressed lipase activity. Other amino acids that were poorly metabolized also caused repression. It was concluded that accumulation of partially metabolized intermediates of amino acid catabolism repressed the synthesis of extracellular lipase. Amino acid analogues may have some potential in the control of hydrolytic enzymes produced by microflora that cause spoilage in food.

FOOD SAFETY AND NUTRITION

Potato nutrient content

The Cu, Zn, K, Fe, Mg, and vitamin C contents were determined and values were compared, using current tables of nutrient data, for seven potato cultivars: Superior, Russett Burbank, Norchip, Shepody, Yukon Gold, Red Pontiac, and Kennebec. The relationship between mineral data from the potatoes and from the soil was also studied. The mean concentrations (in parts per million, on a fresh weight basis) for minerals and vitamin C found in the potatoes were Cu, 1.1; Zn, 3.0; K, 3330; Fe, 4.9; Mg, 213.6; and vitamin C, 64.5 ppm. These values were all lower than those quoted in U.S. Department of Agriculture handbook (8–11) for raw potatoes, with the exception of Mg. The variation in mineral content found in the soil between plots did not appear to correlate with the mineral levels in the potatoes. Mineral content between cultivars differed; Yukon Gold and Shepody, both new releases, were higher in vitamin C than the other cultivars.

Phytic acid and other inositol phosphates

It has been demonstrated that simultaneous determination of inorganic phosphorus and phytate can be achieved using nuclear magnetic resonance (NMR). There are certain advantages to using NMR as it is nondestructive and does not require hydrolysis of phytate to inorganic phosphorus. Both NMR and wet chemical methods were used to determine phosphorus in fishmeal, soybean meal, and excreta from poultry fed both diets. NMR techniques were used to determine phosphorus in oat and Jerusalem artichoke products. In the fishmeal, only inorganic phosphorus was present. By AOAC (Association of Official Analytical Chemists) methods it was found to be 42.2 mg/g, whereas by NMR it was 22.8 mg/g, the difference resulting from the method of acid extraction. In the poultry excreta from the fishmeal diet, the phosphorus was found to be 54.1 mg/g by AOAC and 29.6 mg/g by NMR. Both measurements increased because phosphorus is excreted from the metabolic pool. The phosphorus in soybean meal was exclusively phytate, 3.6 mg/g (AOAC) and 3.0 mg/g (NMR). The poultry excreta from the soybean diet contained phytate, in essentially the same concentration as in the feed, and inorganic phosphorus (8.6 mg/g by AOAC and 6.6 mg/g by NMR). The oat bran samples contained less phytate (4.7–10 mg/g) than most wheat brans. The oat gum contained about 40% of the phytate from the bran starting material. Jerusalem artichoke contained equal amounts (0.3 mg/g) of phytate and inorganic phosphorus. The study showed that simultaneous, quantitative determination of phytate and inorganic phosphorus by NMR is a viable alternative to wet chemical methods.

STRUCTURE AND SENSORY EVALUATION

Vegetable fiber

In FRC's continuing investigation on the vegetable fibers of significance in the Canadian diet, the structure of arabinogalactan from celery was established. An arabinogalactan isolated from celery (*Apium graveolens*) consisted of L-arabinose, D-galactose, and D-glucose residues in the molar ratio of 2.53:1.00:0.12. Data from sedimentation analysis indicated that the polysaccharide was homogeneous. Methylation studies showed a statistical unit of 78 sugar residues with 27 terminal, nonreducing end groups (20 L-arabinosyl and 7 D-galactosyl). There are also 19 residues of L-arabinose involved in branching, including 12 through positions 3 and 5; and 7 through positions 2, 3, and 5. The remaining 32 nonterminal residues consist of eighteen (1→5)-linked L-arabinosyl, nine (1→4)-linked D-galactosyl, and five (1→3)-linked D-galactosyl residues.

Microscopy

Scanning electron microscopy (SEM) was used to demonstrate structural differences related to processing and product quality in several products. Spray-dried retentates, prepared by ultrafiltration of milk, were less susceptible to lactose crystallization because of their lower lactose content. SEM of regular spray-dried milk (SDM) showed crystallization and caking when exposed to humid conditions. In addition, surfaces of spray-dried particles showed less wrinkling than the regular SDM.

Coagulation of milk retentates yielded firm gels with branching casein micelle chains when commercial proteolytic enzymes were employed, the firmest gels being produced with

rennet. Microbial proteases, e.g., *Endothia paracitica*, produced soft gels composed of clusters of casein particles. Coagulation of homogenized retentates resulted in a uniform gel structure in which the dimensions of fat particles were similar to those dimensions of casein micelles.

Electron microscopy revealed differences in the rheological properties of elevated solid content yogurt prepared by traditional methods, by ultrafiltration, and by culturing a milk retentate. Yogurt made from a milk retentate was the firmest.

Grittiness in concentrated milk products, generally believed to be caused by calcium phosphate, was shown by SEM and histochemical analysis to result from compacting of protein particles.

Transmission electron microscopy was applied to elucidate special relationships between collagen, muscle fibers, and fatty tissue in roast pork.

Fluorescence microscopy, SEM, and energy-dispersive X-ray analysis were used to show that globoids of undigested oat phytin remain unaltered as regards structural identity and elemental mineral contents in the gastrointestinal tract of rats.

Sensory evaluation

The Sensory Evaluation Unit provided collaborative research service to several scientists within FRC; to other establishments in the Research Branch, namely Kentville, Smithfield, Brandon, and Nappan; and to Laval University.

Sensory qualities were characterized and quantitated to determine the effect of diet supplements on meat flavor; the graininess quality of applesauce from different varieties of apple; the effect of the Biobone process on cheddar cheese production; and the relation of fishmeal in the poultry diets to off-flavors in poultry meat.

Standardized methods were developed to establish reference standards for four common flavor defects in cheese and butter (sour, bitter, rancid, and fruity). These have been incorporated in the federal dairy grader training program of the Food Production and Inspection Branch.

The Sensory Evaluation Unit conducted a workshop on sensory evaluation methods and techniques for participants from industry and government.

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Departures

S.N. Edey, B.Sc. Retired 31 May 1988	Applications

K.C. Ivarson, B.Sc., M.Sc., Ph.D. Retired 30 November 1988	Soil microbiology
R.K. Jones, B.Sc., M.Sc. Resigned; now with Alberta Research Council	Party Leader, Ontario
J.A. McKeague, B.A., B.S.A., M.Sc., Ph.D. On transfer of work, Tanzania Canada Wheat Project, Arusha, Tanzania, April 1986–April 1989	Soil classification

VISITING SCIENTISTS

A. Buttler, B.Sc., D.Sc. Switzerland	Organic soils
H.Y. Chiow, B.Agric.Sc. Malaysia, CIDA project	Cropping systems
A. Darus, B Agric.Sc. Malaysia, CIDA project	Remote sensing
B. Dumrugs, M.Sc., D.S. Thailand	Pesticide residues analysis
S. Dupont, M.Sc. France	Pesticide residues analysis
A. Faridah, B.Agric.Sc., M.Sc. Malaysia, CIDA project	Land suitability modeling
P. Fauzi, B.Sc., M.Ec. Malaysia, CIDA project	Agricultural economics
G.-Q. Geng, B.S.A., M.Sc. People's Republic of China	Soil degradation
J.C. Gomes, B.Sc., M.Sc. Brazil	Agroclimatic assessment
M.A. Hares, B.Sc., M.Sc., Ph.D. University of British Columbia	Soil physics
F. Karanja, B.Sc., M.Sc. Kenya	Crop modeling
Abd. R. Mansor, B.Agric.Sc. Malaysia, CIDA project	Systems analysis
S. Mohmad, B.Sc., M.Sc. Malaysia, CIDA project	Agroclimatology
E. Pattey, B.Sc., M.Sc. Laval University	Micrometeorology
S.R. Vieira, B.Sc., M.Sc., Ph.D. Brazil	Soil physics
Q. Zhen, B.Sc., M.Sc. People's Republic of China	Geographic information system
H. Zhou, B.Sc., M.Sc. People's Republic of China	Computer applications to soil mapping
H.C. Zhou, B.Sc., M.Sc. People's Republic of China	Cartography

[1] Appointed 25 January 1988.
[2] Seconded to Management Services Division, 8 February 1988.
[3] Seconded to Land Resource Research Centre, 7 March–16 September 1988.
[4] Seconded to Land Resource Research Centre, 12 September 1988.
[5] Effective 1 March 1988.
[6] Effective 1 March 1988.

INTRODUCTION

The Land Resource Research Centre (LRRC) carries out soil surveys and research programs involving soil, water, and agrometeorology. The mandate is to collect, assemble, and integrate information on soil, climate, and surface hydrology in Canada and to undertake research to assess and improve the potential of land for sustained agriculture and other land uses.

Programs of the centre entered their 2nd year since being restructured into multidiscipline studies, which embrace pedology, chemistry, physics, mineralogy, microbiology, agrometeorology, and some other environmental sciences. The benefits of the arrangement became obvious in 1988 in improved interdisciplinary collaboration and flexibility for change.

The Inventory Section, working from a solid technical base, has begun to move soil surveys increasingly from traditional products into applications of the information. Many such applications are facilitated by the updated, computerized Canada Soil Information System (CanSIS). In addition to the traditional field surveys, still much in demand, generalized province-wide maps and digital data bases are being produced. Interpreted products include regional assessments of subsoiling, crop management groupings, application of census data to landscape units, crop insurance risk, and grazing capability. Monitoring activities focused on trends in soil temperature measured at selected sites in relation to other soil characteristics. An interesting application of the geo-information system was to portray the possible sources of pesticide pollution of the Great Lakes on both the Canadian and American sides of the border. For much of the year heads of the soil survey units were assigned to the national soil conservation program to assist with the preparation of background material and the negotiation of federal–provincial agreements. A major conversion of the computerized soil information (CanSIS) from its original custom software to ARC/INFO software has been completed, involving fully 891 maps. The compilation of data files for each area on each of these maps absorbed much of the efforts of the Soil Resource Inventory and Mapping Section during the year.

The Research Section continues to make excellent progress across the broad range of studies that seek understanding of complex physical, biochemical, and microbial processes in soil, as well as the behavior of management systems in the field setting and comprehensive modeling of soil–plant–atmosphere relationships. Much thought was given to reorientation of research, and preparations were made for focusing more resources toward the higher priorities, namely pesticides in the environment, soil conservation production systems, solute movement in the physical system, land evaluation, and climatic risk.

In land evaluation a series of key economic variables have been calculated as estimates of long-term sustainability of agricultural systems. A major simulation model for crop growth, PIXMOD, has now been validated for wheat, and similar models are being developed for forages and for canola. Work has been initiated to refine the concepts of risk areas for crop insurance. Clay mineralogy work has indicated that some clays may have a potential as a selective adsorbent for toxic organic and inorganic substances.

Scientists working on behavior of pesticide residues in soils acquired greater understanding of the processes of microbial degradation and genetic aspects that might be manipulated to increase efficacy and reduce environmental impacts. The data being obtained on crop development in relation to soil thermal and water regimes under conservation tillage systems should prove to be of great value in evaluating models of crop growth and better systems for conservation production. Considerable progress was made in hydrologic characterization of field sites, which to date has been bedeviled by the extreme variability of field conditions. A significant finding with implications for structural stability of soils was that up to a quarter of the organic matter in agricultural soils is made up of wax-like materials. In agrometeorological research, the usefulness of weather-based production estimates made in July for that year's crop production levels in the Prairies was demonstrated. Regional values for carbon dioxide flux obtained by low-flying aircraft were used to relate photosynthetic rates to vegetation indices estimated from satellites.

Additional information can be obtained from the Director, Land Resource Research Centre, Research Branch, Agriculture Canada, Ottawa, Ont. K1A 0C6; Tel. (613) 995-5011.

J.L. Nowland
Acting Director

RESEARCH

Soil quality evaluation and monitoring

The major soil degradation processes were identified by two task forces (eastern and western) on soil quality evaluation and monitoring. For western Canada these processes are erosion by water and wind, disappearance of organic matter, and salinization. For eastern Canada the major degradation processes are water erosion degradation of soil structure (compaction), and acidification. The task forces described the approaches to be used for evaluation and monitoring of soil degradation. Process-based models, as opposed to statistical models, were recommended for prediction of the rate of the various degradation processes. Existing models will be used, if possible. Criteria were established for selecting and characterizing a network of verification (benchmark) sites. The site selection involves stratification of the agroecosystem, including climate, soil texture, soil development, slope, and farming system. The data from periodic sampling and measurement at these sites will be used to evaluate and to modify the proposed models.

Soil quality in the Canadian context brings together six discussion papers that cover: (*1*) identifying the important attributes of good-quality agricultural soils; (*2*) describing the current quality of soil conditions for agricultural production in Canada; and (*3*) establishing a national program for monitoring agricultural soil quality.

Loss of soil quality by erosion

Research at the Central Experimental Farm, Ottawa, has shown that soil erosion has a greater effect on organic matter in the soil than on other soil properties. The loss of surface soil and organic matter leads to a decrease in available nutrients in the root zone. In southern Ontario, rainfall simulation was used to determine the effects of winter conditions, different crop residues and tillage conditions on runoff, infiltration, and soil loss. Soil losses decreased with increasing residue cover and were least from no-till treatments. Attempts at interseeding red clover into corn were not successful at establishing this cover crop sufficiently well to provide significant control of erosion over winter. In eastern Ontario no-till corn can be grown in rotation with hay and cereals, which reduces erosion and improves physical characteristics of the soil, without causing significant losses in yield. Results in the Peace River region of Alberta and British Columbia indicate that the universal soil loss equation may overestimate water erosion in this part of Canada. In Saskatchewan the heavy clays, which are relatively nonerodible by wind in the summer months, are highly erodible in winter and early spring.

Research on ways to predict soil erosion under partly frozen soil conditions has continued. Two empirical methods based on freezing degree days and surface heat flux for predicting the frozen state of the soil were evaluated using field data observed on a sandy loam and a clay loam soil. A physically based approach, which incorporated a finite difference solution to the diffusion equation for heat flow, was also assessed. This approach provided the best agreement between the observed and predicted frost penetration.

Assistance and support were provided for the operation of Soil Conservation Canada and for several provincial soil conservation organizations, to facilitate the transfer of technology and to improve communications. Newsletters, information packages, and resource materials were prepared.

Mineralogy and soil quality

The criteria for mineralogical classes, as defined in earlier research, were combined with information on soil texture to provide a method for mineral classification of 350 subsoils. The resulting information was summarized onto a 1:5 000 000 mineralogical map of Canada. The map units are being interpreted in relation to important soil characteristics, such as potassium supply, swelling, shrinking, and capacity for water retention.

Collaborative research with Ontario scientists identified the cause of potassium deficiency in grapes and other fruit crops in the Niagara region. Soils of loamy and finer texture contain sufficient amounts of vermiculitic minerals, which take up and retain potassium, that a deficiency is caused even under fertilized conditions. The deficiency problem can be alleviated by applying potassium fertilizer at a higher rate and by placing the fertilizer in bands to reduce its contact with the soil.

Research is continuing to evaluate specific surface area of whole soils as an indicator of clay mineral composition and associated soil behavior, such as swelling, shrinking, and water-holding capacity. Attempts are being

made to establish the relationships of agronomically important minor elements in soils to the mineralogy and crop production in relation to element toxicity and deficiency problems.

Mineral analyses services provided 1948 X-ray powder diffractograms, 288 infrared absorption spectra, and 7 Mössbauer spectra to contribute supportive data to at least 21 research papers and reports from research stations. Subjects included mineral characterization of Canadian soils, mineral weathering, soil acidification, acid sulfate soils, clay–organic complexes, clay intercalation with hydroxyaluminum cations, and methodology development for mineral identification and quantification.

Prairie regional land evaluation

New agroecological resource area maps (1:2 000 000) were completed for the three Prairie Provinces, and work is well under way toward development of an integrated, electronic data base of soil–climate–crop yield–management for the region. These data are being developed as one of the main bases of assessing production risk in this area. They are supported by the powerful ARC/INFO geographic information system, which was recently installed in the department.

Procedures were developed for selecting and grouping weather data to obtain a characterization of the daily weather and climate for each agroclimatic resource area. These data are being used to compile a series of essential soil moisture limits by phenological stage for the major crops grown in the region. The best available mathematical models and computerized interpolation techniques are being used for this purpose.

Similarly computer techniques have been developed to characterize and classify cropping systems in the region, using census data from 1981 and 1986. On this basis a series of key economic variables have been calculated as estimates of the economic performance and long-term sustainability of the agricultural systems currently being practiced in each area. These include estimates such as profitability, return to labor, return on investment, annual inputs and costs, and the rate of change of these over time.

The development of computerized simulation models for crop growth is a parallel activity in this project. The spring wheat model, PIXMOD, has been validated for Manitoba and simulations of yield have been performed for all major agricultural soils in the province. These values, based on annual, stochastic weather events and modified by soil and management conditions, have been used to calculate yield probability functions for all agricultural soils in Manitoba. Similar models are being developed for forages and for canola.

Associated with the activities of crop modeling and developing the data base is some new and innovative research on assessing risks in crop production, particularly as these concern such major, safety-net programs as crop insurance. On this basis, work has been initiated to reexamine and refine the concepts of risk areas, soil productivity, crop suitability, and other elements in the program, to provide a more scientific basis for crop insurance and to make it more actuarially sound.

Interactions between inorganic and organic soil components

The solubility and mobility of Al from soil clays under the influence of acidity affects both soil fertility and the environment. Three types of hydroxy–Al–montmorillonite complexes were identified and the initial conditions for drying the complexes were found to be determining factors for the type of solid complex formed. The 28-Å complex had a relatively regular interstratified structure of 9.6- and 18.9-Å component layers. The hydroxy–Al pillars were sparsely but homogeneously distributed in the interlayer space. The height of the pillars was 9.2-Å, which, together with the chemical data, suggested that the Johansson's model molecule, $[Al_{13}O_4(OH)_{24}(H_2O)_{12}]^{7+}$, was most suitable for the pillar. The spongy form and high surface area of the complex has a potential as a selective adsorbent of organic and inorganic molecules.

Low-temperature ashing (0 plasma oxidation) of humic acid (HA) extracted from leonardite (brown coal) and of fulvic acid (FA) extracted from the Armadale Bh horizon showed that the ash contents were 2 and 21.5% in HA and FA samples, respectively. The infrared and ^{13}C-NMR spectroscopy techniques demonstrated a layer-by-layer oxidation process. Analysis for C:N ratio at various stages of oxidation showed that organic N was being oxidized to nitrate and being retained in the inorganic residues. The possibility of nitrate formation and retention must be recognized and taken into account when the low-temperature ashing method is used for the quantitative determination of organic matter in soil samples.

Three Fe–FA complexes, containing 0.80, 1.54, and 4.70% Fe, were prepared in the laboratory. An analysis using Mössbauer spectroscopy suggested that Fe(III) in the complexes occurred partly in the form of organic complexes and partly as inorganic species. A study of the resistance of Fe in the complexes to base hydrolysis showed that iron was associated with the FA by at least two, possibly three, different mechanisms, and that the interaction products exhibited differing chemical stabilities.

The chemical speciation method using high-performance liquid chromatography (HPLC) previously developed for an organic soil has been adapted to an iron-rich mineral soil from south-central New Brunswick. Experimental results indicate that both sorption and hydrolysis can be monitored during the course of a heterogeneous kinetics experiment.

Pesticides in Canadian soils and their uptake by plants

The persistence of EPTC (*S*-ethyl dipropylthiocarbamate) and related thiocarbamate herbicides in soil was shown to be controlled microbiologically. A bacterial strain, TE1, isolated from soil was not only proficient at EPTC degradation but also degraded butylate (*S*-ethyl di-isobutylthiocarbamate) and vernolate (*S*-propyl dipropylthiocarbamate). Addition of the extender dietholate, i.e., *O,O*-diethyl-*O*-phenyl phosphorothioate, to cultures of this bacterium inhibited degradation of all three thiocarbamate herbicides. The inhibitory effect of dietholate on bacterial growth of TE1 and EPTC degradation depended upon dietholate concentration in the medium and lasted until dietholate itself was degraded by TE1 cells.

Microbial degradation of [1-^{14}C-*propyl*] EPTC with the soil isolate TE1 showed that about 68% of the label was liberated as $^{14}CO_2$ and that only 23% was incorporated into the cell biomass. The identity of the initial metabolite (dipropylamine) formed was first inferred from isotope dilution experiments and later established by gas chromatography (GC) and GC–mass spectrometry. The subsequent metabolism of 1-^{14}C-*propyl* moiety of EPTC was deduced by comparison with the utilization of [1-^{14}C]propionate and [1-^{14}C]propylamine. The EPTC-degradation-deficient mutant, TE3, metabolized propylamine and propionate at rates similar to those with TE1. However, TE3 did not degrade EPTC. The mutant, which lacks a 50.5-megadalton plasmid (present in TE1) reported previously to be involved in EPTC degradation, was shown to be defective in the initial ester hydrolytic step of EPTC decomposition.

The effects were investigated of repeated application of prometryn, i.e., 2-(methylthio)-4,6-bis(isopropylamino)-*s*-triazine, when applied to an organic soil already containing bound or freshly deposited prometryn residues. The soil, which was previously treated with [^{14}C]prometryn and incubated for 4 years under laboratory conditions, contained 53.5% of the initially applied ^{14}C in the form of bound residues. Repeated addition of the herbicide to the soil containing formerly bound ^{14}C residues resulted in a decrease in the proportion of the added herbicide bound as residues. The soil exhibited a considerable increase in the thermal decomposition of bound ^{14}C residues by high-temperature distillation.

The mineralization of the pyrethroid insecticide deltamethrin, i.e., (*S*)-α-cyano-3-phenoxybenzyl *cis*-(1*R*,3*R*)-2,2-dimethyl-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylate, and the hydrolysis products 3-phenoxybenzoate and Br_2CA, i.e., 3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylate, were examined in an organic soil and in enrichment cultures. 3-Phenoxybenzoate was much more rapidly mineralized than either deltamethrin or Br_2CA. It appears that the Br_2CA moiety may be quite resistant to microbial metabolism.

Endomycorrhizal infection of corn roots had a significant effect on atrazine uptake, metabolism, allocation, and resistance in corn plants. The herbicide atrazine was removed from soil by endomycorrhizae and was transferred to corn plants. Dyfonate, i.e., *O*-ethyl-*S*-phenylethylphosphonodithioate, residues bound in organic soil were released, taken up, and transferred to onion plants by endomycorrhizae.

The HPLC chemical speciation method, developed for atrazine in aqueous suspensions of organic soil, yielded numerical values for chemical kinetics parameters that are related to persistence in soils, and for sorption parameters that are related to leaching in soils.

A pressure extraction technique previously developed was used to extract the atrazine and its metabolites from plant tissues of bean, soybean, and canola. Single leaves were placed in a pressure chamber, and plant fluids were

collected from the leaf vascular system under applied pressures from 0 to 6.2 MPa. Up to 98% of the total tissue fluid was extracted by this technique. Pressure extracts were directly injected into an HPLC for analysis.

Soil-conserving production systems

The 1988 growing season in eastern Ontario was characterized by an early season drought followed by near-normal conditions. Good yields of both corn and soybeans were obtained with both conventional and moisture-conserving tillage practices. Averaged over two locations, the conventionally produced (moldboard plowing in autumn with one spring disking) corn yield was 9.6 t/ha, whereas that for no-tillage was 8.3 t/ha. Ridge (8.8 t/ha) and chisel (9.3 t/ha) systems produced intermediate yields.

Excellent data sets on crop development as well as soil thermal and water regimes were obtained; these data will be used to evaluate crop growth models, which are essential to the development of better soil and water-conserving production systems for field crops. The data were used to establish relationships between air and seedbed temperatures. Accumulated thermal units were calculated and these, together with data on the field emergence of corn, were used to quantify differences in emergence among hybrids and tillage practices.

Preliminary observations of earthworms indicated higher populations under no-tillage. Acari and collembola populations were also monitored; relationships between faunal populations and soil structure are under investigation.

Soil physical quality in relation to water and solute movement

Extensive hydrologic characterization has been conducted on a field site (located on the Central Experimental Farm) prior to the initiation of experiments in water and chemical transport. Three-dimensional (3-D), field-saturated hydraulic conductivity (K_{fs}), matric flux potential (ϕ_m), the alpha parameter (α), and the antecedent volumetric water content (θ_v) were measured in situ over two depth intervals (6–15 cm, 35–50 cm) at 164 stations on a 10 × 10 m grid. 3-D, vertical, and horizontal K_{fs} were also measured on the site at two depths (50 cm and 100 cm) at 82 stations on a 20 × 20 m grid. The analyses completed to date show that K_{fs}, ϕ_m, and α are highly variable over the field site with similar spatial variability patterns within each sampling depth, but different patterns between depths. As a consequence, the rates and patterns of water and solute movement on the field site may be very complex. With this potential complexity in mind, four detailed monitoring networks have been installed and are being tested. Each network consists of vertical nests of piezometers, water-table wells, time-domaine reflectometry (TDR) probes, and porous suction cups.

A numerical modeling investigation of leakage from unlined, liquid-manure storage pits suggests that simple relationships describing steady, ponded infiltration through a crusted surface into unsaturated soil can be useful in the design and assessment of these and similar storages. A field study showed that the rates and patterns of contaminant leakage depend strongly on the water-table regime, the K_{fs} of the manure crust, the K_{fs} of the underlying soil, and the unsaturated flow properties (α, ψ) of the soil.

Because of its flexibility, the SWATRE numerical model from the Netherlands has been selected as a suitable model for the development and assessment of systems for water-table management. The model is currently being tested using K_{fs} and field data collected at two sites near Ottawa. Field testing of two combined systems for water-table management, surface contouring and underdrainage, continues at Kapuskasing. Field tests in clay soils at Alfred and Alexandria have shown that water-table management using mole drains is feasible provided that the soil meets specific stability and plastic limit criteria.

Theoretical and field investigations have suggested new means by which the soil hydraulic properties, K_{fs}, ϕ_m, α, the wetting front potential (ψ_f), and the microscopic capillary length (λ_m) can be measured at and below the soil surface. Some of these methods should be particularly useful in porous media of low permeability. The λ_m value has been proposed as a possible index of soil structure. Image analysis studies using impregnated soil blocks have suggested that it is not feasible to establish parameters for soil micro- and macro-structure solely on the basis of pore width distribution.

Soil organic matter and composts

A series of greenhouse studies for soil testing and classification of organic soils was completed, having included 55 cultivated organic soils; lacustrine, marine, and alluvial clays, silts, and sands; mineral sublayers; and organic amendments of varying degrees of decomposition. Oats, barley, onions, carrots, lettuce, spinach, and reed canarygrass were grown. One of the interesting conclusions was that even when nutrition, temperature, and available water were nonlimiting for crop growth, yields varied widely seemingly because of differences in amounts of oxygen available for root respiration. Soil quality of cultivated mineral and organic soils may therefore decline as a result of loss of organic matter and compaction, even when water and nutrients have not become limiting to crop growth.

Organic amendments rich in humus, such as decomposed peat and composts, were compared with those rich in more readily biodegradable and hydrophilic materials such as peat and straw. Both amendments improved soil structure and stability. However, the improvement by the polysaccharide-rich undecomposed peat was mainly caused by water-dispersible adhesives. The humified material was four times more effective, on the basis of unit carbon, for improving soil aggregation and structural stability, apparently because of the water-stability and polyvalent cation bridging afforded by the long-chain aliphatics in humus.

Soil organic matter often contains significant concentrations of straight-chain (paraffinic) aliphatics. To identify some of these materials, we extracted whole soils, fine clay fractions, and humic and fulvic acids sequentially with *n*-hexane, chloroform, and supercritical *n*-pentane. Each extract was then analyzed by pyrolysis–soft ionization mass spectrometry. The extracts contained high-molecular-weight *n*-alkanes, *n*-fatty acids, *n*-alcohols, sterols, and *n*-alkyl mono-, di-, and tri-esters. The highest molecular weight compound identified had a mass of close to 1500 daltons. All the components identified have been reported to occur in natural waxes. Our findings suggest that between 10 and 25% of organic matter in agricultural soils is made up of wax-like materials. The latter could positively affect the structural stability of soils.

Climate assessment and information

During 1988, modeling estimates of soil moisture reserves and expected levels of crop production indicated the severity and extent of the heat and drought conditions for the prairies. Weather-based production estimates made in July during 1979–1988 were in excellent agreement with the Statistics Canada data published by the subsequent year.

Vegetative growth and fresh weight of tubers in several varieties of potato were significantly increased in Ottawa by irrigation scheduled using a water-budgeting technique. User-friendly software was calibrated for scheduling irrigation for potatoes and apple orchards.

Collaborative work with the University of Guelph has shown that genetic improvements in photosynthetic response has contributed to increased yields in maize cultivars from 1958 to 1988.

Observations of soil temperature from sites in three provinces and the Yukon were compared with estimates derived from a macro-climatic model to determine effects of drainage, management, and vegetation on soil climate. Comparison of procedures for sampling and analyzing soil temperatures indicated that primary classifiers for soil climate can be estimated reliably by infrequent, regularly spaced sampling over 3 years. Monthly soil temperatures were estimated at 53 locations in the Atlantic region to classify soil climates and to determine risk of extreme low temperatures during winter months.

A cooperative study with the University of Guelph has determined simple criteria for estimating spring and autumn freeze dates at various risk levels and critical temperatures from zonation maps of average frost dates for Ontario. A procedure was developed to estimate seeding dates for corn from climatic data as part of an evaluation of variability in heat units available for corn production in the Maritime region.

A more accurate method of estimating potential evapotranspiration from climatic data was developed for the province of Quebec. Agroclimatic zonations were produced for the growing season and for the cold season in Quebec.

Computer archives of daily meteorological data for more than 500 climate stations in Canada were updated and maintained for a

variety of applications in agrometeorology. These data are available to Agriculture Canada users with access to the AGRINET system.

Assistance was provided to Brazilian scientists under a program, sponsored by CIDA, in development and training in computer software used to estimate soil moisture content and to determine risk of freezing temperatures from long-term daily records under Brazilian conditions.

Crop production

A microcomputer-based system of data acquisition was used for calculation of the fluxes of CO_2, H_2O, and sensible heat. Flux density measurements taking into account all known sources of energy exchange were presented in several publications as an example of the strategy required to control the quality of the data in measuring eddy fluxes under field conditions. The sources of errors and the degree of accuracy that can be obtained for CO_2 and H_2O flux densities were then demonstrated with available instrumentation. Chamber techniques were also used to measure the CO_2 and H_2O exchange at leaf and soil surfaces in a project aimed at scaling up from point values in the crop canopy to field averaged values given by the flux measuring system. A newly developed unit to measure soil gas exchange was used to assess the spatial and temporal variability of soil respiration in a maize crop and on bare ground.

Regional CO_2 flux values obtained by flying at an altitude of 50 m across various transects within a 100 × 300 km agricultural region in southern Manitoba were used to relate photosynthetic rates to vegetation indices estimated from LANDSAT multispectral scanners data. Good relationships were obtained when the data were stratified into soil and vegetation types. Factors that affect airborne flux estimates such as types of sensor used, run length, altitude, environmental conditions, and averaging processes were evaluated and the results were presented at a workshop on the measurement and parameterization of land-surface evaporation flux.

Several years of field measurements of photosynthesis and respiration in maize leaves were analyzed as a function of environmental conditions, plant age, and cultivar type. Significant cultivar differences were found in photosynthesis rates during development, though preliminary analysis did not show cultivar differences in respiration.

Methods have been developed for calculating leaf appearance rates, leaf expansion intervals, and leaf-maturing rates. These methods will be used to improve models of leaf area expansion and phenological development for maize under field conditions.

SOIL RESOURCE INVENTORY AND MAPPING

Mapping

Soil landscapes 1:1 million scale. This long-term project continues. Its aim is to compile generalized descriptions of the soil landscapes of the whole country in the form of a digital data base that can be evaluated for biological productivity and trafficability. Maps are to be published at a scale of 1:1 000 000 showing selected information from this data base. The information is being digitized into the Canada Soil Information System (CanSIS). Each area (polygon) is described by a standard set of attributes stored in the computer files. New mapping was completed in northern British Columbia (40 000 000 ha), southern Yukon (15 000 000 ha), and parts of southern Quebec (40 000 000 ha). Reports and data files have been published for the first five areas: Alberta, Manitoba, Maritime Provinces, southern Ontario, and the island of Newfoundland. Unpublished information has already been used in such projects as prairie regional land evaluation and loss of soil quality by erosion. Other users so far include the International Joint Commission for a regional study of pesticide use and transmission through soils in the watershed of the Great Lakes, British Columbia Ministry of Environment for northern wildlife habitat, and Newfoundland Forestry for regional site productivity.

Detailed regional and local surveys. These surveys are conducted at the request of, and in cooperation with, provincial ministries of Agriculture, Natural Resources, and Environment. They research complex environmental relationships to guide agricultural land managers and planners, but their results are also applied to urban fringe planning, forestry, and wildlife management. Mapping scales vary from 1:100 000 to 1:20 000 (survey intensity levels 4, 3, and 2).

This year field mapping has been completed in the areas of Woodstock–Florenceville, N.B. (7500 ha); Rouville County, Que. (14 000 ha); Elgin County (60 000 ha) and an experimental watershed (2000 ha) in Ontario; the rural municipalities of Rhineland, Pembina, and Hanover, Man. (100 000 ha); Melfort, Wood Mountain, and Cypress Hills, Sask. (1:22 000 000 ha); St. Paul County (200 000 ha) and Gleichen (93 000 ha), Alta.; Promontory Ridge, B.C. (2000 ha); and the Carcross Valley in the Yukon (2000 ha). A number of other soil survey maps and reports are at various stages of compilation, drafting, or editing and, though as yet unpublished, interim information is available. These include Comfort Cove, Nfld.; Pictou and Colchester counties, Cambridge Station, Northumberland Shore, and Annapolis Valley, N.S.; Chipman–Minto–Harcourt area, N.B.; the counties of Verchères, Richelieu, Saint-Hyacinthe, and Chambly, Que.; the counties of Brant, Middlesex, Elgin, and Niagara in Ontario; the rural municipalities of Dufferin, Thompson, Grey, Roland, and Stanley, Man.; the Rhineland, North Norfolk, and Hanover areas of Manitoba; about 18 rural municipalities in Saskatchewan; the St. Paul's and Cardston areas of Alberta; the Gulf Islands in B.C.; and Takhini Valley and Herschel Island in the Yukon.

Some of these surveys (notably some in Nova Scotia, New Brunswick, Quebec, Saskatchewan, and the Yukon) are conducted under federal–provincial agreements such as those of the Economic Regional Development Agreement (ERDA) and the Agricultural Food Development Agreement (AFDA). In these cases scientists from the Soil Resource Inventory and Mapping Section act as contract supervisors or scientific authorities. Examples of soil surveys actually published in the past year are listed under publications.

International soil resources map, 1:1 million scale. This project is international, very similar to the soil landscapes 1:1 million work already mentioned. Precisely because of that similarity, scientists from the Soil Resource Inventory and Mapping Section have been asked to cooperate. The project is being sponsored partly by the United Nations environment program of UNESCO and is being organized by the International Soil Reference and Information Centre, Wageningen, The Netherlands. The purpose is to compile standard soil and landscape information for the whole world (but emphasizing at first the Third World) that can be used to assess broadscale land productivity and soil degradation. So far the structure and proposed contents of the data base have been fixed, and a procedure manual has been written that describes the way in which the data are to be collected. The procedures proposed in the manual were tested and found practicable during a 3-week tour of a pilot mapping area that covers parts of Argentina, Uruguay, and Brazil. Now a number of areas around the world are to be test-mapped, including a portion of the United States and Canada straddling the 49th parallel from Montana into Saskatchewan and Alberta.

Interpretations

Interpretation studies and systems. The section conducts studies that promote the scientific assessment of soil and land for various forms of land use. Some of these studies are linked to a particular survey, whereas others are independent and help to develop assessment systems that ensure consistent results across the country. All published soil surveys contain interpretations for agricultural land uses. In addition a national working group was convened to revise the soil capability for agriculture interpretation system that was used in the Canada Land Inventory 1965–1975, but which is now out of date. The working group proposes to make the system more objective and quantitative by converting the present seven classes into a continuous numeric scale and by integrating the major factors into a single index. This change will require separating the climate, soil, and landscape aspects of the system and basing it initially on an assessment of grains and oilseeds. The climate portion is to use "growing degree days" and "water deficits."

Individual studies are also pursued within provinces. In Prince Edward Island the effect of dense subsoil tillage on the rooting depth of alfalfa is being assessed. In New Brunswick a project, funded by Employment and Immigration Canada, is developing a system for soil–climate–crop performance. This system will group soils into management categories according to their requirements for certain crops. To this end, yield data from alfalfa plots on different soil types were collected and analyzed. Revised interpretations were published for general field crops in the Haldimand–Norfolk and Niagara regions of Ontario. In Manitoba, maps of wind and water erosion risk were published. The project to

evaluate the effect of deep plowing Solonetzic soils was continued in Saskatchewan, as was an evaluation of rangeland productivity for Lands Branch. In Alberta, a number of workshops were held to explain the *Land capability classification for arable agriculture in Alberta (1987)* that was published last year. In addition a method was developed to link census data from Statistics Canada to landscape units and farm management systems for the purpose of land evaluation. In British Columbia, revised agriculture capability maps for the Peace River were tested and used to assist with risk assessments for the Crop Insurance Branch of the British Columbia Ministry of Agriculture and Food. As an extension of this work, a study was started to develop ratings for climate- and soil-based crop risk in the Peace River district. Finally, a grazing capability study was done in the Yukon for the Kluane Regional Planning Commission.

The British Columbia unit is also running CIDA project 600/12419 to design a prototype land evaluation system for Malaysia. The system analyses biophysical, transportation, and economic constraints to agricultural production and allocates the most suitable cropping systems to land areas. It maximizes regional net farm income by optimizing the use of limited agricultural resources. The system, which runs on a desktop computer, uses the latest technology in data base management, geographic information systems, expert systems, and linear programming.

Correlation

Regional correlation. The results of field mapping and manuscripts of soil reports were reviewed to ensure that they meet national standards. These include 27 surveys already listed in the section on "Detailed regional and local surveys" and 14 other field mapping projects.

Correlation studies. Names are given to soils as a means of identifying those with essentially the same characteristics. How far, however, should one name be allowed to spread? From one map sheet to another is reasonable, but could two soils, one in Vancouver Island and one in Newfoundland, with essentially the same characteristics, developed from the same parent material, under a maritime climate, bear the same name? To regulate such problems a map of ecoclimatic regions has been adopted for trial. A particular soil name would be restricted to given areas on the map.

In Nova Scotia, a method was developed and applied to correlate the on-farm surveys of the provincial government's land evaluation and planning surveys (LEAPS), and field work for a reliability study of the Kings County survey was completed. A portion of the 5th international soil correlation tour, which dealt with the characterization, classification, and utilization of Spodosols passed through New Brunswick.

Monitoring

Soil temperature. Soil temperatures continue to be measured within and below the rooting zone at regular intervals at fixed sites in the Maritimes, Manitoba, British Columbia, the Yukon, and the Northwest Territories. These measurements have led to a revised classification for soil climate being developed for display as maps of soil climate. Soil climate has considerable control over plant growth. In addition soil temperature models were calibrated using the measured soil temperature data to determine the accuracy of these models for soils of different texture, drainage, and vegetation cover.

Soil temperatures are also measured on a continuing project to determine the effect of construction of the Norman Wells pipeline on permafrost. This project is a cooperative study with the Department of Indian and Northern Affairs. It appears that such construction can raise the soil temperature significantly, leading to changes in the depth of the active layer, severe subsidence in ice-rich soils, and possible soil erosion.

Regional monitoring studies. Several studies in the regional units can be grouped under the heading of monitoring. For example, in Nova Scotia a project has been started to evaluate the effect of land rolling on blueberry yields and soil properties. This project will involve developing methods to measure compaction and express it by such means as compactibility indices. In the same vein, a project in New Brunswick is evaluating, in conjunction with McCain's Foods Ltd. and the Fredericton Research Station, the effect of stone crushing on soil properties. In Ontario a mapping study has been done, using the CanSIS ARC/INFO system of computerized soil information (see below), to record the

application of agricultural pesticides. This work is being done for the whole of the Great Lakes basin at the request of the committee of the Great Lakes Water Quality Board of the International Joint Commission that deals with nonpoint source pollution. A second stage involves connecting information about the application rates to that of soil and land use. In addition, reports have been published on agricultural pollution sources, pesticides, and pollution in the south Sydenham River watershed, and the potential for soils to transfer pesticides to water systems in southern Ontario. In Manitoba, in addition to monitoring soil temperatures, there is a program to monitor soil hydrology, pH, and certain heavy metals. Monitoring sites for airborne pollutants continue to be established in that province as well.

Paleosol Research. In 1987 a fossil forest with relict and buried paleosols was discovered on Axel Heiberg Island in the high Arctic. This year, scientists from the Soil Resource Inventory and Mapping Section visited the site with a multidisciplinary team supported by the Polar Continental Shelf Project of Energy, Mines and Resources. They mapped, described, and sampled the soils and buried peat deposits to help recreate a picture of this anomalous Tertiary forest that now sits far north of the Arctic Circle, but whose nearest modern equivalent appears to be something like the Florida Everglades.

National soil conservation program

Accords, Agreements, and Work Plans. From February to October 1988 the heads of each of the regional units of the Soil Resource Inventory and Mapping Section were assigned to the national soil conservation program. Reporting to the executive director general, their responsibilities were to help with the negotiations that would lead to the accords, agreements, and work plans for each province specifying what was to be done under the program. Two major reports were also produced, which detailed, for western and eastern Canada, the support activities, such as the development of a computerized geographical information system and a program to monitor the effects of soil conservation practices, that a national program such as this would require.

Canada Soil Information System (CanSIS)

ARC/INFO conversion and file compilation. The computerized soil information system that stores, analyzes, and displays data about the characteristics and productivity of the major soils in Canada is now running on ARC/INFO software. The conversion from the custom software that had been developed by LRRC since the early 1970s is now complete.

All maps that were previously digitized, and those which were deemed important and reliable enough by the provinces to become part of the new system, have been converted to ARC files. These maps total 891. The conversion was intended for contracting out but proved too expensive. The staff of the Information Systems and Cartography Unit eventually did it, working shifts between September 1988 and March 1989. At the same time, a national CanSIS working group established the structure and contents of the info files that will hold records of the attributes of all soils shown on these maps. There are files for each area on the map (polygon file); each unique map symbol (soil map unit file); each soil, or nonsoil, listed in the legend (soil name file); each horizon, or layer, in a soil (soil layer file); and each survey project (project file). A core set of attributes was established for each file. These attributes are mandatory. They must be recorded before information about the project will be stored in CanSIS. Much of the effort of the Soil Resource Inventory and Mapping Section this year has been spent on compiling all these files for the converted maps. This task has been enormous because not all the information was in the old CanSIS system. Indeed, in some of the older surveys, not all the information was available in the originally published maps and reports. To date, soil map unit, soil name, and soil layer files have been completed for 450 maps. They have been partially completed for 300 more, as have all the project files. Work has also started on writing all the operating manuals that will explain what CanSIS now is and how to use it.

Further work next year will concentrate on (*1*) completing the standard national files, (*2*) digitizing and compiling files for important published maps that were never put into the old system, (*3*) augmenting the national standard files with additional data that are required by particular provinces, and (*4*) determining the full requirements for all

national files in future projects. Some of the major regional units of the Soil Resource Inventory and Mapping Section are also being supplied with microcomputer-based systems of soil information so that CanSIS will gradually be converted to a country-wide network from a central Ottawa system.

The CanSIS system has been used extensively this year by such internal LRRC projects as prairie regional land evaluation and the distribution of clay minerals in Canada. In addition, information has been transferred to external clients. For example, New Brunswick requested soil information for the provincial computerized agricultural land information system. Manitoba Hydro received soil information for the Lac du Bonnet area and connected it to land use and forestry data to assess routes for hydroelectric lines. The Geography Department of the University of Regina and Canada Centre for Remote Sensing each received the 1:1 million soil landscapes map of Alberta in digital form for the purpose of environmental studies. Parks Canada also received map information in digital form as part of the continuing cooperative mapping project for national parks, which included data for Waterton Lakes, Prince Albert, Elk Island, and the Kootenays.

Cartography

Printed maps and graphics. Besides their increasing role in the operation of CanSIS the staff of the Information Systems and Cartography Unit prepare maps, diagrams, and figures to be printed for centre and departmental publications. For some time there have been suggestions that much of the unit's work could be contracted out. Consequently, the Bureau of Management Consulting conducted a review of their program in the early part of this year. They concluded that although many activities could be contracted out, in whole or in part, the unit's services are required and well regarded by its clientele, and that there are no particular strong or attractive advantages to contracting them at present. Nevertheless, the unit has had to undergo some internal reorganization to fulfill its greater responsibilities for CanSIS.

This year the unit completed 15 soil projects comprising a total of 171 maps for the department and 14 new maps and 9 map reprints for Environment Canada. Ten maps showing groundwater contamination by pesticides were produced for Food Products and Inspection Branch, and eight special projects, such as conference displays, and 394 miscellaneous jobs were completed for the department. A total of 53 new projects for the printed map program and the Canada Soil Information System were received and started during the year.

A piece of cooperative work with the Correlation Unit and CanSIS staff was the development of standard format products to be produced automatically from the ARC and info files of CanSIS. So far standard formats, for a soil map with soil symbols or polygon numbers and for derived and interpretive maps, have been produced. It is intended also to develop a standard soil description from the info files that can be inserted directly into future soil reports or soil fact sheets.

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F.D.H. Macdowall, B.Sc., M.Sc., Ph.D. Retired December 1988	Legume physiology
Y.C. Paliwal, B.S.A., M.Sc., Ph.D. Died 23 June 1988	Aphid- and mite-transmitted viruses

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INTRODUCTION

In 1988, the internal restructuring of the Plant Research Centre (PRC) was completed, and the nine sections of the former Ottawa Research Station and the Chemistry and Biology Research Institute were consolidated into three programs: plant biotechnology, plant–microbe interactions, and plant breeding and management. From October 1987 to February 1988, PRC conducted an exhaustive review of its past and current activities to determine what kind of research the centre should conduct in the next 5–10 years in response to the national agricultural strategy and, more specifically, to the new Research Branch strategy. This exercise involved nine review panels consisting of a total of 46 external reviewers from industry, universities, provinces, and other national and international research establishments. The critical analysis of the comments and recommendations from these reviews resulted in the development of a strategic plan, which identifies PRC's capabilities to address the needs of the Canadian agri-food sector for long-term research and technology transfer. An improved mechanism is in place for effective delivery of programs through 3 research programs and 16 studies. Details of the research activities to be conducted in PRC are being developed within the framework of the overall commitment of the Research Branch to industry and its research partners.

Activities of the centre covered a broad spectrum of plant research, ranging from characterizing plant and microbial genes to cultivar release of selected crops, and involved research and development as well as technology transfer. Highlights of research achievements in 1988 include: the determination of specific growth conditions of donor plants to optimize haploid plant production from anther culture of wheat; the isolation and complete nucleotide sequencing of a storage protein gene from cruciferous plants and construction of vectors to regulate its embryo specific expression; the sequencing of satellite RNA of lucerne transient streak virus, and the demonstration that it is partially homologous to an Australian strain of the virus; the mapping on a megaplasmid of *Rhizobium meliloti* of the membrane transport genes essential to the fixation of symbiotic nitrogen; the evaluation of large numbers of wheats for mycotoxin tolerance; the recommendation for licensing of a new, soft, white winter wheat that has resistance to the prevalent race of smut; and the development of a number of techniques that can contribute markedly to the development of hybrid alfalfa.

These and other research activities are reported in the 56 research publications and 29 miscellaneous papers listed.

The productive partnerships with the other research players, in universities, provincial organizations, and industry, is reflected in the increasing number of collaborative agreements. Twelve PRC professionals are currently appointed as adjunct/associate professors at five Canadian universities (Carleton, Ottawa, New Brunswick, McMaster, and Guelph). Several others are involved in university thesis committees, granting councils (NSERC), and three centres of excellence: monocot transformation; plant protection; and *Brassica juncea*, Canada's future oilseed crop. The international recognition of PRC as a centre for basic research in plant science has attracted 20 visiting scientists, 10 NSERC fellows, 20 graduate students, and 7 scientists on contract.

In 1988, the director of PRC managed three research programs, the national office of the Plant Gene Resources of Canada (PGRC), and the operations for the 500-ha Central Experimental Farm (CEF). The operations include the maintenance of the CEF grounds, the arboretum, the ornamental gardens, growth facilities, and experimental fields for PRC and other CEF establishments. PRC is also responsible for assets management and services, the Research Branch motor vehicle fleet, campus security, and services to the national livestock "showcase herds."

PRC also provides research service to other establishments and universities in electron microscopy, nuclear magnetic resonance, and mass spectroscopy.

It is with deep sorrow that I also have to record the untimely death of Dr. Y.C. Paliwal, who was an outstanding scientist in PRC and who was known internationally for his work on plant virus diseases. His scientific contributions to plant virology and Canadian agriculture have left a remarkable imprint. His sudden death has left behind a void that will not easily be filled.

This report summarizes only some of the more important research activities on the basis of programs and studies as well as research-related services. Further information can be obtained from the publications listed at the end of this report. Reprints of the research publications and copies of this report are available on request from the Director, Plant Research Centre, Research Branch, Agriculture Canada, Ottawa, Ont. K1A 0C6; Tel. (613) 995-3700.

W. Baier
Director

BIOTECHNOLOGY

Cell biology and somatic cell genetics

To further characterize embryogenic microspores in *Brassica napus* L., changes in nuclear morphology and in lipid, protein, and carbohydrate content during pollen development were examined. Cytoskeletal studies of microspores during embryogenic induction revealed extremely rapid reorganization of microtubules from gametic to somatic developmental patterns. The inductive mechanism is being examined at the cytoskeletal and biochemical levels.

Two cell lines resistant to the herbicide chlorsulfuron derived from mutagenized microspore cultures of *B. napus* were further characterized biochemically and physiologically. Biochemical evidence suggests a novel enzyme system of resistant acetolactate synthase (ALS), however, these cell lines are nonmorphogenic. Experiments were initiated to recover this mutation in *B. napus* plants by somatic hybridization. Conditions for protoplast isolation, culture, fusion, and selection levels of herbicide have been established.

Cell suspension cultures of *Arabidopsis thaliana* Heyhn. were used as model systems for the demonstration of assymetric fusion as a method of gene transfer into *B. napus*. Conditions for the X-ray inactivation of *Arabidopsis* protoplasts were established with 60 000 rads inhibiting cell division by 80%. Following fusion, several *B. napus* plantlets that possess limited *Arabidopsis* genetic information were regenerated.

High-frequency plant regeneration from long-term *Arabidopsis* cell suspensions was used to transform this model species with bacterial reporter genes β-glucuronidase, neomycin phosphotransferase, and chloramphenicol acetyl transferase.

Experiments were undertaken to identify and purify the mitochondrial polypeptides involved in cytoplasmic male sterility in *B. napus*. A protein of molecular mass 60 kilodaltons was identified in the male sterile mitochondria, whereas another protein of molecular mass 12 kilodaltons was identified in response to a nuclear restorer gene.

Protoplast isolation, culture, and plant regeneration protocols for several cultivars of tomato (*Lycopersicon esculentum* Mill.) and the sterile hybrid between *L. esculentum* × *Solanum lycopersicoides* Dun. were developed. Protoplast fusion experiments between tomato and this chilling-tolerant hybrid have been performed, and more than 75 putative hybrids are being evaluated for their chilling tolerance and fertility.

The use of protoplasts from transformed plants was tested as the basis for a new system for somatic hybridization selection. Protoplasts from transformed *Nicotiana tabacum* L. plants with a marker gene for antibiotic resistance have been fused with protoplasts of the wild species *N. debneyi* L. containing another gene for antibiotic resistance. Selection for hybrid cells on both antibiotics has been successful, and putative hybrids are being characterized.

Another novel system for selection of hybrid cells, based on sorting fluorescence-activated cells, has been tested with protoplasts of *B. napus* and *Thlaspi arvense* L. (stinkweed). The conditions for vital fluorescence-staining, cell-sorting parameters and recovery of double-labeled heterokaryons has been established.

Developmental physiology

The expression of agronomically important traits such as storage lipid biosynthesis and the induction of freezing and desiccation tolerance in relation to embryo and seed development was studied in *Brassica* and *Medicago* species.

Fatty acid biosynthesis of storage lipids from developing microspore-derived embryos of *Brassica napus* was investigated. The

temperature at which embryos were cultured during early stages of development markedly affected embryogenesis. Embryo development was severely inhibited at 25°C and was arrested completely at 20 and 35°C. Initial culture of microspores at 32.5°C for 4 days, followed by transfer to 25°C, resulted in high yields of well-developed embryos. Fatty acid composition of total glycerolipids was similar for all treatments except for the cultures grown at constant 32.5°C in which levels of the 18:2 and 18:3 fatty acids were significantly reduced. The fatty acid distribution of triacylglycerols changed markedly during embryogenesis. In freshly isolated microspores, the levels of 16:0 and 18:3 fatty acids were relatively high, whereas 18:1 was low. During embryo development, 16:0 and 18:3 decreased rapidly, and the content of 18:1 increased to about 60% of total fatty acids. The proportion of triacylglycerols in the total lipid extracts increased dramatically during embryogenesis until it attained levels comparable to those observed in dry seed.

Cooperative projects were initiated with the Plant Biotechnology Institute and Macdonald College to investigate biosynthesis of lipids in microspore-derived embryos and embryo homogenates of *Brassica*. Preliminary results have shown that radioactive lipid precursors are readily incorporated into all major classes of complex lipids and at rates equivalent to, or greater than, those reported for other developing oil seeds. These observations indicate that the development *Brassica* microspores should provide an excellent system by which to generate the basic knowledge of fatty acid biosynthesis required to improve the quality of canola oil using biotechnology.

cDNA libraries, in λ gt10, were constructed from fully expanded leaves of cold-acclimated and nonacclimated *Brassica napus* L. 'Jet Neuf' and *Arabidopsis thaliana* 'Columbia'. As a first step to identify genes specifically expressed during cold hardening, differential screening (primary and secondary) of over 45 000 clones from the acclimated *Brassica* library was carried out by hydridization with single-strand cDNA probes prepared from acclimated and nonacclimated *Brassica* poly A mRNA. Positive clones obtained are being characterized.

Ribosomal RNA was found to double during cold acclimation in both *B. napus* and *A. thaliana*. To gain some insight into the role of this process in relation to the development of freezing tolerance, the origin of the increase was studied using an *Arabidopsis* rDNA probe. Although a doubling of rDNA cistrons was observed during cold acclimation in *B. napus*, no such amplification occurred in *Arabidopsis*. Similarly, hybridization of restricted genomic DNA with an rDNA probe suggested the presence of increased ecoR1 sites during cold acclimation in *B. napus* but not in *Arabidopsis*. These rDNA changes may be related to a requirement for low-temperature vernalization in *B. napus* rather than to the induction of freezing tolerance. RNA polymerase I activity associated with the chromatin fraction was also found to double in *B. napus* during cold acclimation.

Methods were developed to induce freezing tolerance in microspore-derived embryos of winter *B. napus*. Mefluidide was found to be superior to abscisic acid (ABA) in the induction of freezing tolerance. Plants regenerated from embryos of winter *Brassica*, which were acclimated in culture with a combination of ABA/mefluidide and low temperature, did not require low-temperature vernalization for flowering.

An electrofusion technique to produce new hybrids from selected commercial and wild species of *Medicago* was developed in cooperation with the Plant Science Department, University of Alberta. Protocols for the in vitro culture of *Medicago scutellata*, *M. disciformis*, *M. rugosa*, *M. lupulina*, *M. marina* as well as *M. sativa* were established and the in vitro performance of selected lines was evaluated under optimized electrofusion conditions. Regeneration from commercial alfalfa lines was generally found to be higher than that observed in the wild species.

Two in vitro approaches to micropropagate selected parental lines of alfalfa for hybrid seed production were developed. One technique, developed in cooperation with the plant breeding program, combines rooting and tissue-culture mediums in one container to produce a fully rooted plant from an unorganized cell suspension in about 2 months with no transfers required. A second technique was developed in cooperation with the departments of Crop Science and Botany, University of Guelph. It is the production of artificial seed (i.e., dried somatic embryos) by the use of static and liquid tissue-culture methods combined with induction of desiccation tolerance and the subsequent controlled drying of the clonal material. This

approach has the added advantage of long-term storage capability. The artificial seed technology will likely have significant applications in the area of international exchange of clonally maintained germplasm as well as in the production of hybrid crops.

Cytogenetics and molecular cytology

Cereal cytogenetics. Plant tissue culture has become a powerful tool not only for plant propagation but also as a means of applying techniques for biotechnology to crop improvement. Leaf sections from *Triticum aestivum* L. 'Chinese Spring' and × *Triticosecale* Wittmack 'Welsh' were used as explants as an alternative to immature embryos. Using 15-day-old seedlings from seeds grown aseptically, 15-mm lower sections of third and fourth leaves were sectioned into 5-mm sections and were cultured on Kao's medium supplemented with 2 mg/L of 2,4-D. Both species showed nearly identical frequencies of callus induction at 64 and 63% for Chinese Spring and Welsh, respectively. The frequency of plant regeneration from callus was considerably higher in Welsh at 31%, compared to Chinese Spring at 18%. Studies on meiotic chromosome behavior of regenerated plants revealed no aneuploids but low frequencies of chromosome irregularities expressed as univalents or trivalents and quadrivalents, which were indicative of chromosome translocations. The frequency of meiocytes with chromosomal abnormalities was considerably higher in Welsh than in Chinese Spring and may be the basis for the considerably higher frequency of morphological somoclonal variants that were observed in that species. The frequency of micronuclei per tetrad (which is indicative of chromosomal irregularity) in Chinese Spring regenerants varied from 1.7 to 12.4%, whereas the range of Welsh was 22.1–62.2%.

Cereal tissue culture. Low-temperature growth conditions (10°C day/5°C night) for anther donor plants during 4 weeks prior to the mid-uninucleate pollen stage improved the anther culture response of seven winter cultures of *Triticum aestivum* L. Green plants were obtained from all the cultivars at a mean frequency of 1.5 per 100 anthers. Anthers cultured at 25°C did not yield green plants but at 30°C microspore callus production was increased 25-fold and green plants were regenerated. Albinism occurred in all the cultivars but the degree of expression was genotype dependent. For the production of green plants, ficoll (10%) medium was superior to liquid or agarose media; the relative production of albinos was decreased eightfold in Norstar showing that culture conditions can influence and possibly negate this problem.

Restriction fragment length polymorphism. DNA from eastern Canadian two-row barley cultivars Atlanta, Birka, Herta, Micmac, and Rodeo was examined at the molecular level. Restriction fragment length polymorphisms (RFLPs) were detected using an 18 + 26 S ribosomal DNA and two B hordein storage protein probes. A 5 S ribosomal probe revealed no differences. Such RFLPs are useful fingerprints for cultivar identification and provide a measure of the genetic variation in this germplasm.

Extensive interspecific variation in 18 + 26 S ribosomal DNA was observed in multiple *Hordeum*, *Agropyron*, *Elymus*, *Secale*, and *Triticale* accessions. Polymorphisms in both 18 + 26 S and 5 S ribosomal DNA sequences, observed between wheat and *Agropyron distichum*, have potential as genetic markers in the development and evaluation of the corresponding amphiploid and chromosome addition lines.

Molecular cytogenetics. DNA from *Secale cereale* 'Petkus' was nick-translated to cytological preparations of × *Triticosecale* 'Welsh' and a wheat–rye translocation stock (1BS/1RS) called Kavkaz. The hybridized biotin probe was detected with the streptaviden horseradish peroxidase conjugate and was developed with diaminobenzedine tetrahydrochloride. Under the appropriate hybridization conditions the labeled probe would label rye and wheat DNA differentially. A mixture of labeled rye and unlabeled wheat DNA (1:1) has given the best results.

It was confirmed that Welsh triticale contains six pairs of rye chromosomes and no interchanges are apparent. Similarly, it was confirmed that Kavkaz contained a complete arm translocation (1BS/1RS).

Similarly, biotin-labeled total DNA extracted from *Thinopyrum distichum* (*Agropyron distichum*, *Elytrigia disticha*) preferentially labeled the Thinopyrum chromosomes in a *Triticum durum–Th. distichum* disomic addition line. The technique can be expanded to many intergeneric and interspecific combinations.

Tissue culture and cytology. Callus culture of immature embryos (8 days) of *Hordeum vulgare* 'Golden Promise' (two-row) was highly regenerable, whereas the cultivar Himalaya (six-row) would not regenerate. The F_1 hybrids behave like Golden Promise, therefore regenerability was completely dominant. Segregation patterns in backcrosses and F_2 hybrids suggested that two to three major genes could be involved in the regeneration differences but that minor genes or epistatic interactions could play a part.

Molecular genetics

The gene coding for the 1.7 S storage protein in *Arabidopsis thaliana* has been isolated and the complete nucleotide sequence has been established. The transformation vectors needed to identify regions of the gene that regulate embryo-specific expression have been constructed. A detailed analysis of 1.7 S storage protein mRNA in various tissues of *Brassica napus* 'Topas' indicated developmental regulation of transcription in embryos and in microspores induced to undergo embryogenesis. The expression of this gene as a marker for embryogenic competence is being assessed.

Several members of the acetohydroxyacid synthase gene family have been isolated from *B. napus* 'Topas.' Extensive nucleotide sequencing of two members has been completed. An equivalent *A. thaliana* mutant gene has been introduced into *B. napus* 'Westar' and breeding lines advanced to generate sulfonylurea-resistant lines. The use of this gene as a selectable marker has been examined in detail in both *B. napus* and *Nicotiana tabacum*. cDNA clones of the genes expressed in *B. napus* 'Topas' have been isolated and are being analyzed.

Transformation vectors have been constructed with a hamster metallothionein II gene and the same gene fused to a reporter gene. Both were constructed in a manner that enhanced expression in roots. Transgenic lines of *N. tabacum* 'Delgold' have been generated to assess the protection of leaf tissues from contamination with cadmium.

Transgenic canola lines have been generated with genes responsible for resistance to sulfonylurea herbicides. Transgenic tobacco lines with animal genes that code for protein that sequester heavy metals have been generated.

PLANT–MICROBE INTERACTIONS

Disease epidemiology and resistance

Snow molds. Damage from snow molds in Ontario fields of winter wheat was trace to light in 1988 because of a relatively light and nonpersistent snow cover. However, in test plots on which snow cover persisted for 129 days, winter kill reached 60–100% in lines being screened for resistance. Field experiments using three *Typhula* species that cause snow mold in Ontario were carried out to examine whether saprophytic behavior may contribute to the severity of snow mold disease. Under natural winter conditions isolates of the three species were capable of colonizing nonliving tissues of winter wheat and of using these substrates as a food base for further development, including spread of disease and production of sclerotium. The number of *Typhula* sclerotia formed on the nonliving host tissues varied with the species but a substantial contribution was made to the sclerotium population in the soil. The sclerotia showed physiological and morphological characteristics similar to those produced in culture. These field studies and earlier laboratory work on the competitive saprophytic ability of the three *Typhula* species indicate that saprophytic capability is of some significance in the epidemiology of snow mold.

Loose smut of wheat. All the white wheat cultivars grown in Ontario were susceptible to race T10 of loose smut (*Ustilago tritici* (Pers.) Rostr.) in inoculation studies. However, two advanced lines from the PRC program have proven resistant to both race T10 and race T2 in 2 years of testing.

Crown rust of oats. Virulence on the formerly resistant oat cultivar OAC Woodstock (resistance gene Pc 39) comprised 90% of the crown rust (*Puccinia coronata*) isolates tested from Ontario in 1988—a substantial increase over 1987 levels. However, an oat line from the PRC breeding program with resistance to the race affecting Woodstock has been registered as the cultivar Newman.

Fusarium ear mold of corn. Inheritance studies with the ear-mold-resistant inbred C0272 indicated that this line carries a single dominant gene for resistance to the pathogen *Fusarium roseum* var. *graminearum* (Schwabe) Snyd. & Hans. In field inoculation

experiments, the F_2 and backcross generations of C0272 with susceptible lines exhibited Mendelian segregations for resistant to susceptible of 3:1 and 1:1, respectively. Of 85 inbred lines inoculated in the field, 6 exhibited good resistance to infection by the ear-mold pathogen, whereas the remaining 79 were rated very susceptible.

To determine the status of susceptibility to ear mold among recommended Ontario corn hybrids, and to study the feasibility of a continuing program of testing, 240 hybrids were inoculated in the field with *F. roseum* var. *graminearum*. Significant differences in amount of visible infection were observed.

Other diseases of corn. A survey of corn fields at 76 locations in Ontario showed that, although disease severity was less than in 1986 and 1987, incidence of three major corn diseases was greater. Anthracnose, caused by *Colletotrichum graminearum* (Ces.) G.W. Wils., identified for the first time in Canada in 1984, was found at 32 locations and as far east as Ottawa. Stewart's wilt (*Erwinia stewartii* (E.F. Sm.) Dye) was present at 69 of the locations and was severe in areas suffering drought stress. Ear mold (*F. roseum* var. *graminearum*) was found in all fields examined and was severe at 15 locations.

Brown spot of soybean. Yield losses of up to 16% were experienced in field plot studies of brown spot (*Septoria glycines* Hemmi) in 1988, using eight cultivars and lines (Maple Arrow, Maple Glen, Apache, Bicentennial, OAC Scorpio, KG30, Altona, and NK S09-70). These results confirm earlier findings with a different set of cultivars that brown spot can cause significant yield losses in soybean.

Pathogen–host–environment interaction

Fungal diseases. Effects of cold stress on symptoms of Phytophthora root rot (*Phytophthora megasperma* Drechsler f. sp. *medicaginis*, Kuan & Erwin) of alfalfa (Medicago sativa L.) were examined in greenhouse and field conditions for 4 years. Freezing alone was the main cause of death of plants and it did not produce any dark root lesions that are typical of the disease. Severe winter stress favored disease development in a susceptible cultivar (Vernal) causing significant yield loss.

Five terpenoid compounds, sesquiterpenes and diterpenes, isolated from leaves of adult sunflower plants were tested for their antifungal activity against two important sunflower pathogens. All five terpenoids significantly inhibited the hyphal growth of *Sclerotinia sclerotiorum* and *Verticillium dahliae* within 24 or 48 h. In addition, germination of *V. dahliae* spores was inhibited by two of these terpenoids. Wild sunflower populations have been shown to contain much larger quantities of terpenoids, including those used in this study, than sunflower cultivars and are known to be far more resistant to certain pathogens. The results of this study demonstrated that at least some terpenoids may play an important role in the defence of sunflower against diseases.

Virus diseases. A complete cDNA copy of the viroid-like satellite RNA of the Canadian strain of lucerne transient streak virus (LTSV) has been cloned and the nucleotide sequence of the RNA has been determined using this and other clones. The sequence comprises 322 residues and shares 80% homology with satellite RNAs (stRNAs) of the Australasian isolates of LTSV. A proposed secondary structure for the RNA is highly base-paired and thermodynamically stable and consists of a rod-like structure interspersed with single-stranded loops. This arrangement is similar to that proposed for circular stRNA of other strains of LTSV and other sobemoviruses as well as for viroids. Whereas certain regions of the sequence are very similar or identical to those of stRNA from Australasian LTSV, including the putative self-cleavage sites on both the positive and negative sense forms of the RNA, other regions of the sequence in the Canadian and Australasian strains are quite dissimilar.

Mycoplasma diseases. Periodic infectivity assays of inoculum prepared from the grass-feeding leafhopper *Elymana sulphurella*, after they had fed on barley plants infected with the eastern strain of aster yellows (EAY) disease showed that the causal mycoplasmalike organism (MLO) was still present in the insects 8 weeks after they were removed from the infected plants, indicating that the pathogen was multiplying in the insect. Subsequent transmission experiments showed that 26 and 30% of the leafhoppers were capable of transmitting EAY-MLO from barley to barley following 7- and 14-day acquisition access feeds, respectively. Although *E. sulphurella* does not normally survive on dicotyledonous plants, it can survive on aster plants infected

with EAY, and 16% of the leafhoppers transmitted the pathogen to barley from aster following a 14-day acquisition access period. This species is only the second leafhopper shown to be capable of transmitting this strain of aster yellows.

An indirect procedure of enzyme-linked immunosorbent assay (ELISA), using polyclonal antibodies, was developed for detection of the MLOs that cause aster yellows (AY), clover phyllody (CP), and eastern peach-X (EPX) diseases in various crops. The MLO-antigens were detected in both purified and partially purified preparations from infected plants. The minimum detectable concentration for AY-MLO was 0.08 µg/mL and for both CP- and EXP-MLO 0.31 µg/mL. Further immunological assays showed that the indirect ELISA was at least 15 times more sensitive than direct ELISA in detecting MLO-antigens in samples from diseased plants. Attempts to detect AY-MLO in individual vector leafhoppers by indirect ELISA were unsuccessful. The results suggest that the concentration of MLO in samples prepared from individual leafhoppers was below the detectable limit and that some modifications in the indirect ELISA procedure will be required before it can be used for the rapid detection of MLO in individual insects.

Eighteen stable hybridoma cell lines secreting antibodies against EPX-MLO were produced by fusion of murine myeloma cells with splenocyctes of BALB/c mouse immunized with partially purified preparations from infected celery plants. Nine of the 18 hybridomas that gave the highest absorbence values to infected celery preparations in ELISA tests were cloned by limiting dilution. Further immunoassays for specificity tests were carried out using a MLO-associated panel consisting of four strains of aster yellows, clover phyllody, elm yellows, paulownia witches'-broom, sweet potato witches'-broom, maize bushy stunt, and little peach diseases. None of the preparations from plants infected with these diseases reacted with the selected nine monoclonal antibodies.

Fusarium toxins in wheat and corn

Fusarium graminearum resistance in wheat and corn. Further studies of the effects of the trichothecene mycotoxin deoxynivalenol on protein synthesis by polysome preparations from wheat cultivars resistant and susceptible to *Fusarium* head blight were refined and extended. It is now clear that ribosomes of highly resistant winter and spring cultivars can be as much as 20 times more tolerant to one of the most potent inhibitors of the peptidyl transferase enzyme known, compared to susceptible cultivars. The enzyme is likely modified as is the case of trichothecene-resistant yeast mutants, which helps to explain the considerable trichothecene tolerance of tissue of resistant cultivars. Recent reports have demonstrated that resistance to the head blight involves some new protein synthesis in wheat plants after infection. Cultivars lacking the trichothecene tolerance system are unable to synthesize new proteins after initial infection and, hence, are more rapidly colonized by the pathogen resulting in more mycotoxin in the crop. The identification of specific proteins involved in the trichothecene tolerance system offers a useful approach to the selection of resistant material in vitro and in the field without the necessity of time-consuming experimental inoculations. These principles were further verified in 1988 through the evaluation of 250 bread wheat lines by in vitro resistance test in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT). All the material classed as resistant using the results of many years of trials in the CIMMYT *F. graminearum* nursery was identified using the test developed at our research centre.

Corn inbred material that had been identified as partially resistant to maize ear rot was examined for the effects of deoxynivalenol on protein synthesis by leaf tissue. A heritable difference in trichothecene tolerance between partially resistant and highly susceptible inbreds was found. This finding suggests that trichothecene tolerance is involved in *F. graminearum* disease of corn as is the situation in wheat.

Fusarium metabolite studies. Eight new minor metabolites from a western Canadian strain of *F. sporotrichioides* were characterized. They were all hydroxylated apotrichothecenes, some of which were acetylated. The use of NMR techniques such as 1H/1H correlated spectra (COSY) and nuclear Overhauser effect (NOE) difference spectra permitted the stereochemistry of these molecules to be determined. Three isolates of *F. avenaceum* were studied for their ability to produce enniatins, phytotoxic cyclic depsipeptides. Mixtures of enniatins A/A1 and B/B1 were obtained from the mycelia. Conditions were established for the separation of these isomers using

high-performance liquid chromatography. These compounds were found to bind to alkali metals. A study done using FAB–mass spectroscopy suggested that enniatin complex formation is related to the size of the alkali atom, potassium being optimum. Reports that nivalenol was found in Canadian wheat and barley samples prompted further examination of Canadian and foreign strains of *F. crookwellense* for metabolite production. This species is the probable source of any nivalenol in grain because Canadian strains of *F. graminearum* do not produce this compound. Isolates from several countries (including Canada, Finland, the Federal Republic of Germany, Yugoslavia, Poland, Australia, and southern Africa) pro-duce similar patterns of 3- and 3,4-oxygenated trichothecenes including nivalenol and fusarenone. These compounds are more toxic than deoxynivalenol. Studies of Chinese isolates of *F. graminearum* have shown that the distribution of strains producing the different toxins of this species is the same as in Canada, in contrast to the pattern found for Japanese strains. Preliminary studies of toxigenic strains of *F. moniliforme* have identified a number of new compounds for this species including culmorin analogues.

Rhizobium–legume symbiosis

Genetics. The dicarboxylate transport (*dct*) genes of *Rhizobium meliloti* have been cloned and mapped on the *exo* megaplasmid. Molecular characterization of these genes has revealed that one gene, *dctA*, is the structural gene for the membrane transport protein. Two others, *dctB* and *dctD*, encode regulatory proteins required for sensing extracellular dicarboxylates and for activation of *dctA*. Aspartate has been discovered to be a substrate for this transport system, along with succinate, fumarate, and malate. Dicarboxylate transport is essential for symbiotic nitrogen fixation, because these compounds serve as the carbon and energy sources for bacteroids in the nodule. Cloning and characterization of these genes is a prerequisite to increasing their activity to provide more dicarboxylates for support of nitrogen fixation.

A series of *R. meliloti* Tn5 mutants altered in the ability to proliferate within the nodule has been used to isolate new genetic loci implicated in the synthesis of exopolysaccharides or lipopolysaccharides, which are also required for early stages of nodule formation. These loci are being studied in a scientific cooperation between the Federal Republic of Germany and Canada. Analysis of the mutants by complementation studies has shown that they are grouped into at least five regions in the genome. Cosmids containing four of these regions have been isolated. They contain genes that are involved in processing of side chains of the polysaccharides, such that excess polysaccharide of incorrect structure is produced by the mutants.

A cloned internal fragment of the insertion sequence IS*Rm1*, which occurs naturally in *R. meliloti*, has been used to probe and positively identify the genomes of strains isolated from the field. Proof of identity is based on the location and number of copies of IS*Rm1* in the genome, a trait that is unique and sufficiently stable to be an effective fingerprint of the strain. Identification can be made from free-living bacteria or bacteroids extracted from nodules. The method has been adapted for use with nonradioactive probes and is sensitive enough to identify the occupants of single nodules. Supercoiled plasmids, which are normally found in vegetative cells of *R. meliloti*, are not detectable in bacteroids. However DNA-probing showed that no rearrangement of plasmid genes active in symbiosis takes place during nodule development in strain SU47 or Balsac. Some genomic instability, involving the chromosomal integration and integration of a 150-megadalton plasmid, was observed in vegetative cells of strains related to JJ1c10.

It was reported previously that symbiotic gene probes hybridized to cryptic plasmids of indigenous *R. meliloti*. The presence of the full complement of common nodulation (*nod*) gene sequences on a large, cryptic plasmid (300 megadalton) of an indigenous isolate of *R. meliloti* was demonstrated by hybridization of individual common *nod* A,B,C, and D gene probes derived from the *R. meliloti* megaplasmid with the cryptic plasmid DNA. Differential hybridization intensities of these probes with cryptic plasmid DNA suggest that the reiterated genes may have originated from species other than *R. meliloti* by genetic exchange. Studies are continuing to assess the significance of reiterated symbiotic genes on cryptic plasmids and the contribution to symbiotic and competitive properties of *R. meliloti*.

Physiology. The vanadium-containing nitrogen-fixing enzyme system was found to have more nitrogen-reducing activity than

conventional molybdenum systems when tested at temperatures below 10°C in vitro. Diazotrophs expressing the vanadium system would therefore possess an evolutionary advantage over those limited to molybdenum nitrogenase at lower ambient growth temperatures. The vanadium nitrogenase has been fully characterized in a joint research project with scientists at the AFRC Laboratory of Nitrogen Fixation Research in the United Kingdom. Cyanamide, a new alternate substrate for conventional nitrogenase was found to discriminate between the molybdenum and vanadium systems, providing an additional means of testing for the expression of the vanadium system.

The isolation of intact bacteroids, having high levels of respiration-supported nitrogenase from the alfalfa–*Rhizobium meliloti* system, has allowed direct characterization of nutrient transport systems in these cells. Of the wide range of potential nutrients tested, only 4-carbon dicarboxylic acids were actively accumulated within the bacteroids and supported nitrogenase activity at physiological substrate concentrations. Aspartate accumulation required much higher substrate concentrations and was inhibited by the dicarboxylates. The results of studies on bacteroid transport and nitrogenase activity have led to the partial elucidation of pathways of energy utilization and nitrogen assimilation in bacteroids and whole alfalfa nodules. The enzyme system requires large amounts of ATP to function but the demonstration of tight binding of ADP to both the nitrogenase proteins has contributed to understanding the mechanism of nitrogenase action under nonideal conditions in vivo. Intracellular ratios of ATP to ADP prevent nitrogenase from having the maximal predicted activity.

Transfer of nitrogen from plants of alfalfa (*Medicago sativa* L.) to timothy (*Phleum pratense* L.) was assessed by the isotope dilution method with ^{15}N-nitrate and quantitatively confirmed by the ^{15}N content of the grass and by changes in its total nitrogen. In this work 3% of the total nitrogen fixed by the alfalfa was transferred into 10% of the nitrogen content of the timothy. The biosynthesis of significant levels of γ-aminobutyrate in alfalfa, was followed starting from ^{15}N- and ^{14}C-labeled glutamate and glutamine. Asparagine synthetase was purified 300-fold from root nodules of alfalfa, and its kinetic properties, its subcellular localization, and its activity during plant development and after cutting were examined. Its activity fell 90% after inhibition of nitrogen fixation by cutting or by removal of oxygen, unlike a 20% loss of glutamine synthetase activity, which probably made use of catabolic ammonium.

Ecology. Indigenous populations of *Rhizobium meliloti* represent a major constraint to the establishment of inoculant strains in nodules of the host plant. An understanding of the factors responsible for variation in predominance of diverse types within such populations may assist in elucidating problems of inoculant strain establishment in soils harboring native rhizobia. Multi-isolate inocula for *Medicago sativa* consisting of 30 representative phage types from each of two defined natural populations of *R. meliloti* were employed to determine whether frequency of occurrence in nodules of field-grown plants is related to ability to occupy nodules when equally represented in an inoculum (intrinsic nodulating competitiveness). The absence either of significant correlation or of any other obvious relationship suggest that factors other than intrinsic competitiveness, such as original distribution in soil, determine the relative frequency of indigenous *R. meliloti* in nodules of the host grown in the field.

PLANT BREEDING AND MANAGEMENT

Crop biochemistry and utilization

Digital image analysis was used to determine the variations in kernel morphology between classes of Ontario wheats and between cultivars of soft white winter wheats.

Using external morphology, kernels could be assigned to classes but cultivars within the soft white winter wheat could not be clearly distinguished. Whole kernel features alone were inadequate for correct cultivars classification but the addition of crease or bran features improved cultivar identification.

A collaborative research program with industrial partners was also initiated to assess with digital image analysis the genetic diversity of oat kernel characteristics in relation to oat processing.

The large and small starch granules from wheat have been isolated, cleaned, and purified and the proteins associated with these two

populations have been extracted. Electrophoretic determination of the distinctive protein patterns associated with each population is in progress.

The evaluation of genetic and environmental influences on mixed linkage β-D-glucans in oat kernels was continued and broadened to include nondomestic oats to improve the genetic data base for this trait.

Crop physiology

Low-temperature stress. A program has been initiated to determine factors controlling the overwintering of winter *Brassica napus* in eastern Ontario. Observation trials at Ottawa over the last several years have indicated good survival in about 50% of years, with excellent yields from surviving stands. In controlled environments using survival tests on intact plants, significant variation in tolerance to freezing and to ice among a number of cultivars and lines of *B. napus* and *B. campestris* have been observed. Field experiments to determine the effects of planting date on survival and to determine changes in cold hardiness during winter are in progress.

Using a set of 21 lines in which individual chromosomes of hardy Cheyenne winter wheat are substituted into unhardy Chinese spring wheat, evidence has been obtained that ice tolerance is programmed on different chromosomes than freezing tolerance. Additive effects on cold hardiness of six chromosomes from all three genomes were seen, whereas there was a predominant effect of chromosome 5D on ice tolerance.

A close relative of cultivated corn, *Zea diploperennis*, has been reported in the Russian literature to overwinter where temperatures of −5°C are common. Verification of its low-temperature tolerance using a cold chamber demonstrated 100% survival over several weeks at 2°C, which is much greater tolerance than that found in Canadian grain corn cultivars. This species crosses readily with grain corn lines so it is possible that improved low-temperature tolerance and growth can be transferred to grain corn for areas of 2000 corn heat units in central Canada.

A portable fluorometer was used to study low-temperature stress on photosynthesis in grain corn lines. Elite lines, which grew well at temperatures as low as 12°C, showed less cold stress than those growing poorly. In a parallel study, tolerance to overnight chilling of these lines also showed the same trend indicating that new lines under selection for good low-temperature growth also possess good resistance to chilling.

Hard red spring wheat. An experiment was designed to examine the effects of varying seeding rates and nitrogen rates on yield and quality parameters of hard red spring wheat using the Canadian cultivars Katepwa and Columbus and the European cultivar Max. The test was seeded at six locations in Ontario during 1987 and 1988. Yield increased significantly with 60 kg/ha nitrogen fertilizer but decreased or remained the same with higher nitrogen levels. Seeding rates of 350 and 450 seeds per square metre resulted in the highest yields. The European cultivar Max yielded significantly more than the Canadian cultivars, however, it did not yield enough to compensate for its lower economic return per tonne. Maximum economic yield was achieved by growing Katepwa wheat with no nitrogen input. Grain protein concentration increased as nitrogen fertilizer increased. However, the response was variable and did not warrant recommending increased nitrogen rates.

Preharvest sprouting of wheat. Resistance to pre-harvest sprouting of entries in the Ontario winter wheat screening and cooperative tests was visually evaluated on threshed grains from spikes that were exposed, in the field, to heavy rain and high humidity for 4 days. Among the commercial cultivars, Fredrick and Augusta were the most resistant with about 20% sprouting grain, whereas Houser had the worst performance with almost 50% of sprouted kernels. In both tests, there were lines with performances similar, but not better than the best checks. Over 800 lines from the PRC breeding program were also evaluated and lines with improved performance were selected.

Management of forage and corn insect pests

Alfalfa weevil. Since the late 1970s, populations of the alfalfa weevil (AW) in southern Ontario have fluctuated within narrow limits, generally at subeconomic levels. However, periodic eruptions exceed the damage threshold. The driving variable is *Zoophthora phytonomi* (Arthur), a fungal pathogen that causes disease epizootics in the weevil nearly every year. Recent studies have shown that the first incidence of disease occurs after the accumulation of 204 degree-days (DD) base 9°C

from 1 April. Epizootics begin at 261 DD and continue for 10 days to 2 weeks, killing up to 99% of the larvae and about 50% of the cocooned stages. It is apparent that there are three conidial cycles of the fungus that shower (discharge conidia) at intervals of 55–60 DD. The first cycle showers when the AW larvae are small but is coincident with epizootics of the disease in overwintered larvae of the clover leaf weevil whose infections magnify the supply of inocula. The second cycle showers at peak incidence of the third instar, and the third, just subsequent to peak incidence of the fourth instar. Larvae infected during the fourth instar die in their cocoons and produce resting spores that overwinter in the ground litter. In 1988, unusually dry weather in May and June inhibited conidial discharge and AW epizootics failed to develop for only the second time in the past 15 years. Life tables for three bellweather sites in the Quinte area show that survival rates for the pest exceeded 20%, which foreshadows a sharp increase in numbers for 1989.

Alfalfa snout beetle. During its 2-year life cycle, the alfalfa snout beetle overwinters as a mature larva and as an adult, respectively. Field studies showed that the new adults move to the soil surface in early April and remain inactive for several days. Migration and feeding begin in mid April in response to seasonal increases in temperature, and the onset of migration is phenologically associated with full bloom of wild serviceberries, *Amelanchier* spp. Ovarian development begins within 10 days of migration and the first eggs are laid in early May. The eggs are deposited in the soil near the alfalfa crowns to a depth of 5 cm. The larvae hatch in early June and the first two instars feed on the root hairs and fine lateral roots, gradually moving deeper in the soil. The third to fifth instars feed at depths of 20–40 cm but the final two instars move upward to feed on the tap roots at levels of 5–10 cm. In late fall, the fully fed larvae retreat to a depth of 20–30 cm and hibernate until June of the following year when they pupate. The resulting adults remain dormant for about 9 months. In 1988, a study was carried out to determine the longevity of the adults in bales of hay. To simulate harvest conditions, marked specimens were fed into the compression chamber of a commercial forage crop harvester and were baled with the hay. Living adults were recovered from the bales for up to 46 days of storage, indicating that baled hay should not be shipped from infested farms for a prescribed period.

Alfalfa blotch leafminer. During the early to mid 1980s, Ontario populations of the alfalfa blotch leafminer (ABL) collapsed owing to the attack of *Dacnusa dryas* (Nixon), a parasite introduced from Europe. Detectable populations of both host and parasite have since persisted. Survival of ABL is attributed to a defence reaction in which the third instar host encapsulates and kills the egg or first instar parasite. This phenomenon has reduced the level of parasitism by about 10% in each generation but its incidence is independent of host and parasite densities. Encapsulation has provided a dampening effect, resulting in what appears to be a state of equilibrium that assures co-existence of both host and parasite.

European corn borer. The European corn borer overwinters in eastern Ontario as a mature larva in the stalks and stubble of corn. In 1988, it pupated in mid June and the adults emerged 2 weeks later. Moth flight and oviposition peaked in mid July following the accumulation of 1406 corn heat units (CHU) after 10 May. The larvae fed on the leaf tissues within the whorls, then bored inside the stalk at the base of the tassels before moving to the ear zone where they fed on the ear shoots and leaf sheaths. By mid September (ca. 2500 CHU) they had descended to the lower 30 cm of the stalk and were undisturbed by harvesting practices. The bivoltine strain accounted for 8.5% of the total population.

Genetics of wheat improvement

The soft white winter wheat 0-90-4-1 outyielded the mean of the yield check varieties in test area I (southwestern Ontario) for 3 years in the Ontario cooperative test and so is a candidate for registration. Its pedigree is 8077B92-1/Tecumseh//Fredrick from crosses made in 1975 and 1977 at Ottawa. It was advanced by head-to-row selection in the field from F_2 to F_8 with emphasis on strong straw, large heads, and general agronomic performance. F_4 and F_5 rows were selected for low grain protein, as its three parents had somewhat higher protein than desirable for a pastry wheat.

0-90-4-1 averages 1 m in height and has very strong straw. It and a sister line, 0-90-5-1, were the only entries in the cooperative test with resistance to race T10 of loose smut (*Ustilago tritici* (Pers.) Rostr.), which is the

prevalent race in Ontario. 0-90-4-1 had less leaf spot (*Septoria tritici* Rob. ex Desm.) than all but one of the cultivars recommended for Ontario. It had less *Fusarium* head blight (*Fusarium graminearum* Schw.) than Augusta and Frankenmuth.

0-90-4-1 has lower grain and flour protein than most cultivars recommended for Ontario. Its sprouting resistance equals that of the better checks and surpasses that of Houser.

The weaknesses of 0-90-4-1 include lower yields in test areas II and III than the mean of the yield checks; poorer winter survival than most checks and lower 1000 kernel weight. It has the same susceptibility to powdery mildew (*Erysiphe graminis* DS ex Merat) and leaf rust (*Puccinia recondita* Rob. ex Desm. f. sp. *tritici*) as currently recommended varieties.

Genetics of oats and barley improvement

Oats. A new, covered, seeded, milling-type oat named Newman (OA774-1) was registered in Canada (No. 2947) in 1988 and released to SeCan Association for distribution to growers. It resembles the popular PRC oat Donald but possesses genes for resistance to prevalent races of crown rust in Ontario. It is anticipated that Newman will be useful as a food oat, and as a feed oat for horses and in the mixed grain trade because of its plump, white seed of high hectolitre weight.

Naked oats are gaining popularity as a specialized feed for pigs and poultry and Quaker Oats, Robin Hood Multifoods, and Nabisco expanded their evaluation of the naked oat Tibor and the experimental strain OA753-2 for food uses. So far no processing problems have been recorded by any company. Genetic mechanisms have been discovered and used in breeding programs to reduce the percentage of covered seeds in grain samples of naked oats, and to reduce the number of hairs (trichomes) on the surface of oat groats, which act as skin and respiratory irritants after being liberated into the air during threshing and handling. A new strain of naked oats OA826-3 outyielded, at eight locations in Ontario, the standard naked oat Tibor by an average of 24% and the groat yields of covered seeded check cultivars Ogle by 11% and OAC Woodstock by 18%.

Barley. The PRC six-row barley cultivar Leger is still the standard for yield and adaptability in eastern Canada. However, a new standard for yield may be established with the registration of two new PRC two-row barley cultivars OB751-12 and OB751-27. Support for registration has been obtained from the Ontario Cereal Crops Committee and an official registration request is being processed. In addition to expressing high yield, they have high test weight, large seed, mildew resistance, and excellent lodging resistance. Another new six-row barley strain OB942-1 has performed well as a 1st-year cultivar in the eastern cooperative test and has resistance to mildew from two-row barley. A few promising lines derived from somaclonal variation experiments have reached the stage at which they will be evaluated in the Ontario preliminary barley test in 1989.

Corn breeding and genetics

The 1988 growing season was long and above normal in heat unit accumulation. Major moisture deficits did not occur at Ottawa but were severe at Pakenham and Cobden, which are two new short-season test locations of 2400 and 2200 CHU respectively.

Several new elite inbred lines have been identified. These resulted from second and third generations of C0109 as the recurring early source together with excellent agronomic characteristics of the B14 family.

The use of silk inoculation for screening S2 lines began and was effective in detecting resistance to *Fusarium graminearum*. Severe root lodging resulted from a violent storm in early August following silking. As a result of an imposed stress of high population density and a corn borer infestation, some 60–70% of S2 lines were discarded.

Cooperative studies in the Maritimes (Prince Edward Island, New Brunswick, and Nova Scotia) have shown that early adapted corn hybrids are being developed. Corn can now be evaluated as an alternate feed grain in the region. Similarly, for the 2nd year in a row, several new early hybrids matured at La Pocatière, Quebec.

A study of growth chamber conditions under which corn is selected for good growth at low temperature demonstrated considerable within-chamber horizontal variability in temperatures. By carefully rotating the position of plants three times a week, this variability was minimized and a day temperature of 12°C was identified as being most useful to select elite plants. Seedlings from cycle-one selection for good low-temperature growth survived and

showed slow, steady growth over 28 days at 12°C, whereas unselected material showed only limited growth from seed reserves followed by death after 10–14 days.

Soybean breeding and genetics

Experimental lines were rated visually for response to natural daylength extended to 20 h using incandescent lamps (outdoors) and using cool white fluorescent lamps (greenhouse), then classified at the E3/e3 and E4/e4 maturity loci. Analysis of F_2 and $F_{2:3}$ populations from five crosses revealed that only the e3e3e4e4 genotype is insensitive to a 20-h photoperiod outdoors. To explain this insensitivity, a model of two loci (E3/e3 and E4/e4) each with two alleles, each with dominance, plus epistasis of E3 on e4, is proposed.

Early maturing, nondwarf, determinate soybean plants were isolated from crosses with the Japanese cultivar Kitamishiro (PI 317334A). Test crosses confirmed that these plants, and Kitamishiro, carried the maturity gene E1 and the stem termination gene dt_1 normally found only in cultures from the southern United States. They also were of the genotype e3e3e4e4 and hence insensitive to long photoperiods.

Genetics of forage quality

Forage research is focused on developing more effective breeding strategies and on investigating factors that affect forage quality.

A technique using transplant plugs was developed to facilitate the commercial production of hybrid alfalfa seed. Hybrids are known to outyield significantly traditional synthetic cultivars, but commercial production has not been possible because of the need to propagate parental clones vegetatively. Using this new technology, which involves mass production of somatic embryos in tissue culture, alfalfa clones that carry regeneration gene(s) are multiplied in a form that can be transplanted directly to seed production fields. Laboratory evaluation of the plug is complete and field testing is under way.

Forage grass genotypes differing in digestibility have been shown to exhibit different spectral absorption characteristics using microspectrophotometry. The initial results of this cooperative project with the U.S. Department of Agriculture Plant Structure and Composition Research Unit, Athens, Ga., has confirmed the potential of using in situ microscopic techniques to investigate chemical factors affecting digestibility in forage.

Digital analysis is being used to examine factors that affect digestibility in forage grasses. Initial studies of intact stem and leaf tissue indicate that digestibility is more closely related to structural differences in cell wall components than to percent tissue type.

Genetic variability for protein breakdown during ensiling was identified in timothy. Proteolysis resulting from the action of plant enzymes during ensiling has an important negative effect on forage feeding value. Replicated growth room and field experiments revealed highly significant differences among timothy genotypes for proteolysis, as measured by amino acid production in chopped samples incubated for 4 days at 30°C.

ELECTRON MICROSCOPY AND SPECTROSCOPY SERVICES

More than 80 professional and technical staff, from establishments on the Central Experimental Farm (CEF), from research stations at Smithfield, St. John's, and Fredericton, and from outside agencies such as Ottawa University, Carleton University, University of New Brunswick, University of Guelph, and Ottawa Civic Hospital, made use of the facilities of the Electron Microscopy Unit. Visiting scientists from India and the People's Republic of China were trained in operation of transmission and scanning electron microscopes. Research done at the unit was reported in 30 research papers and reports covering biosystematics of fungi, plants, and insects; ultrastructure of meat and dairy products; soil structure; freezing injury in plants; viral studies; study of food products at low temperature; development of rapid freezing techniques; and image analysis and three-dimensional reconstruction from serial sections. These publications are listed in individual reports of research centres and stations. New techniques have been developed at the unit for presentation of three-dimensional structural detail in fungal taxonomy, for examination of frozen food products by scanning electron microscopy at low temperature in the frozen state, and for scanning electron miroscopy of internal structure in freeze-fractured cells and tissues. The IPS-Kontron image analysis system was updated with new programs extending its range of operation.

The Nuclear Magnetic Resonance (NMR) Unit was augmented by the installation of a high-resolution 500-MHz NMR spectrometer. This new technology has proved invaluable for the structure determination of the uridine-diphosphate-disaccharide fragment from cytoplasmic cofactor involved in methane synthesis, as part of a continuing study on the characterization of novel lipids and cofactors from *Methanobacterium thermoautotrophicum*. The improved resolution was used to determine the configuration of several new apotrichothecene derivatives from *Fusarium sporotrichioides* through the use of two-dimensional NMR and nuclear Overhauser enhancement techniques. In addition, an NMR method for the quantitation of phytate in variety of feed extracts was developed. In collaborative research, the unit provided high-field NMR service to Carleton University and the National Research Council of Canada as well as to other research centres at the CEF.

More than 1100 samples were analyzed by mass spectroscopy for scientists at CEF, National Health and Welfare, and the universities of Toronto and Moncton. Fast atom bombardment, an increasingly useful and relatively new technique, was adapted successfully to determine the structure of a broad range of labile natural products. The data-handling capacity was increased by interfacing an IBM PC-compatible computer to the MS data system.

PLANT GENE RESOURCES OF CANADA (PGRC)

The PGRC central office is the essential element of a national program the goals of which are to obtain, maintain, conserve, and evaluate collections of crop germplasm, to organize national and international exchanges of plant genetic material, and to provide information and documentation on all the above.

Refurbishment of the PGRC building continued in 1988 and six mid-term and two long-term seed conservation units with 162 and 272 m^3 of storage capacity, respectively, were installed and made fully functional. PGRC maintains more than 84 700 seed samples, including national base (CN) and active (PGR) collections. Principal world base collections of oats and barley as well as duplicate collections of pearl millet, rapeseed, and mustard are conserved as Canada's contribution to international genebank activities. In 1988, 5181 accessions were involved in exchanges of germplasm with individuals and institutions in 27 countries. Smithfield Experimental Farm was designated as the primary national repository for clonally propagated genetic resources.

Information on Canadian national collections (oats, barley, wheat, tomato, and alfalfa) is stored in computerized data banks. Enhancement of data base management is under way. The bilingual PGRC newsletter, published semiannually, reports on plant genetic resources activities. It has an extensive mailing list in Canada (>700) and 55 other countries.

PGRC provides a national focus for Canadian activities in plant genetic resources. Consultations are held with various crop committees. A genetic evaluation workshop was organized successfully and held at the 26th World Genetic Congress. Also a National Clonal Genetic Resources Workshop was held to develop recommendations for conservation and utilization of clonally propagated plant germplasm.

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Eastern Region
Région de l'Est

Y.A. Martel

D. Demars

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Program Director *Directeur des programmes* — D. Demars, B.Sc., M.Sc., Ph.D.

PREFACE

The Eastern Region, with headquarters in Ottawa, consists of 10 research stations, two research centres, eight experimental farms, and several substations. These research establishments serve the agricultural communities in six provinces, namely Newfoundland, Prince Edward Island, Nova Scotia, New Brunswick, Quebec, and Ontario. In 1988, the region managed a budget of about $74 million and employed some 360 professionals to carry out its programs. Research programs in 1988 encompassed the following in the three areas.

Atlantic Provinces: soil management, which includes the development of practical technology to cope with erosion, drainage, and the physical constraints related to impermeable subsoils; livestock and livestock feeds research, to develop improved feeding and management systems with particular emphasis on the utilization of locally produced feedstuffs for beef and dairy cattle, swine, and poultry operations; cereal research, concerned with developing and identifying superior cereal cultivars meeting regional requirements for yield, disease, cold tolerance, and climatic adaptability; forage crop research, to develop superior forage management techniques and the breeding and testing of new cultivars; and horticultural crops research on potatoes, other vegetables, tree fruits, berries, and ornamentals.

Quebec: soil conservation and improvement, to establish optimum fertilization rates for various crops and continued studies to obtain strains of *Rhizobium* more resistant to low temperatures and endomycorrhizae specific to various crops; livestock research, designed to improve feeding and management systems for beef cattle, dairy cattle, swine, and sheep; cereals research, to develop and identify superior cultivars that meet the needs of Eastern Canada; forage research, developing new varieties and improved crop management techniques; horticultural research, focusing on various types of vegetables, orchard fruits, aromatic plants, and ornamentals; and food processing research, using biotechnology and food engineering to develop new technology for processing dairy, meat, and plant products and extending storage life.

Ontario: multidisciplinary field crops research and development, aimed toward developing new varieties and generating appropriate crop husbandry practices for soybeans, winter wheat, field beans, and horticultural crops; sandy soil research on tobacco and tobacco alternate crops; pest management for orchard and vegetable crops; animal and plant research, developing improved beef production systems for northern Ontario and western Quebec; pest management and environmental toxicology and quality research, involved with reducing the dependence of the agri-food industry on pesticides; and research on food processes, improving the quality, safety, and nutritive value of food.

Staff changes in 1988 included the following. Dr. Claude Aubé, director at Saint-Jean-sur-Richelieu, was appointed as director at the Saint-Hyacinthe Food Research Centre, replacing Dr. René Riel who retired; Dr. J.C. St-Pierre, director at the Lennoxville Research Station, was appointed as Director General, Central Experimental Farm.

Further information about our programs may be obtained by contacting the establishment concerned or by directing inquiries to Eastern Region Headquarters, Research Branch, Agriculture Canada, 930 Carling Avenue, Ottawa, Ont. K1A 0C5; Tel. (613) 995-7084.

Y. Martel
Director General

PRÉFACE

La Région de l'Est, située à Ottawa, comprend dix stations de recherches, deux centres de recherches, huit fermes expérimentales et quelques stations satellites. Les établissements de recherches dispensent leurs services aux collectivités agricoles dans six provinces, soit Terre-Neuve, l'Île-du-Prince-Édouard, la Nouvelle-Écosse, le Nouveau-Brunswick, le Québec et l'Ontario. En 1988, la Région a géré un budget de 74 millions de dollars et a employé quelque 360 professionnels pour mener à bien ses programmes. Les programmes de recherches en 1987 comprenaient ces trois régions.

L'Atlantique: l'aménagement des sols comprend le développement de technologies pratiques destinées à résoudre les problèmes d'érosion, de drainage ainsi que des contraintes physiques liées aux sous-sols imperméables; les recherches sur les bestiaux et leur alimentation mettent au point des régimes d'alimentation et des pratiques d'élevage susceptibles d'accroître l'utilisation du fourrage produit localement pour les bovins de boucherie et les bovins laitiers, les porcs et la volaille; les recherches sur les céréales sont axées sur la création et l'identification de cultivars supérieurs susceptibles de répondre aux besoins régionaux; les recherches sur les fourrages améliorent les techniques culturales, sélectionnent et essaient de nouveaux cultivars; les recherches horticoles incluent la pomme de terre, d'autres légumes, les fruits de verger, les petits fruits et les plantes ornementales.

Le Québec: le programme de conservation et d'amélioration des sols vise à établir des taux optimums de fertilisation pour différentes cultures; il mise aussi à obtenir des souches de *Rhizobium* plus résistantes aux basses températures et des souches d'endomycorhizes spécifiques à plusieurs cultures; les recherches sur le bétail ont pour objet d'améliorer les systèmes d'alimentation et de conduite des bovins de boucherie, des bovins laitiers, des porcins et des ovins; le programme de recherches sur les céréales a pour objet de développer et d'identifier les cultivars supérieurs capables de satisfaire les besoins de l'est du Canada; le programme de recherches sur les plantes fourragères vise à mettre au point des techniques supérieures de gestion des cultures; les recherches en cultures horticoles portent sur diverses espèces de légumes, les fruits de vergers, les plantes aromatiques et les plantes ornementales; la recherche sur la commercialisation des aliments fait appel à la biotechnologie et au génie alimentaire pour développer de nouvelles technologies et de nouveaux procédés de transformation de produits laitiers, carnés et végétaux.

L'Ontario: les activités pluridisciplinaires de recherches et de développement sont axées sur la création de nouveaux cultivars, la mise au point de pratiques culturales appropriées pour le soja, le blé d'hiver et le haricot ainsi que sur des cultures horticoles; la recherche sur sol sablonneux de tabac et d'une culture de remplacement; les études sur la lutte intégrée contre les ravageurs des cultures de vergers et des productions maraîchères tentent de réduire l'épandage de pesticides chimiques; le programme de recherches sur les animaux et sur les plantes vise la mise au point de systèmes améliorés d'élevage de bovins de boucherie pour le nord de l'Ontario et l'ouest du Québec; les recherches sur la lutte intégrée contre les ravageurs, sur la toxicologie et la qualité de l'environnement visent à diminuer les pesticides; les recherches sur les aliments s'efforcent d'améliorer la qualité, l'innocuité et la valeur nutritive des aliments.

En 1988, il y a eu certains changements dans le personnel: le Dr Claude Aubé, directeur à Saint-Jean-sur-Richelieu, a été nommé directeur au Centre de recherches alimentaires de Saint-Hyacinthe; il a remplacé Dr René Riel qui a pris sa retraite. Le Dr J.C. St-Pierre, directeur à Lennoxville, a été nommé directeur générale de la Ferme expérimentale centrale à Ottawa.

Pour obtenir de plus amples renseignements sur nos programmes, il faut écrire aux établissements concernés ou adresser les demandes à l'Administration centrale de la Région de l'Est, Direction générale de la recherche, Agriculture Canada, 930, avenue Carling, Ottawa (Ont.) K1A 0C5; Tél. (613) 995-7084.

Y. Martel
Directeur général

Research Station
St. John's West, Newfoundland

PROFESSIONAL STAFF

K.G. Proudfoot, B.Agr., M.Agr.	Acting Director

Agronomy

D.B. McKenzie,[1] B.S.A., M.Sc., Ph.D.	Forages

Horticulture

K.G. Proudfoot, B.Agr., M.Agr.	Potato and rutabaga breeding
M.C. Hampson, B.Sc., M.Sc., Ph.D.	Potato diseases
B.G. Penney, B.Sc., M.Sc.	Vegetable and berry crops
G.A. Bishop, B.Eng., M.A.Sc.	Agricultural machinery; land drainage

VISITING SCIENTIST

R.F. Morris, B.S.A., M.Sc., F.E.S.C. Honorary Research Associate	Insect fauna of Newfoundland and Labrador

[1] Appointed March 1988.

INTRODUCTION

The research station of approximately 70 ha is located at an elevation of 116 m, 5 km west of the city of St. John's. Research is conducted on forages, vegetable production, peat soils, native lowbush blueberries, and control of potato wart disease and golden nematode. The station has a total budget of $1.5 million and 31 person-years.

Additional information can be obtained from the Research Station, Research Branch, Agriculture Canada, P.O. Box 7098, St. John's, Nfld. A1E 3Y3; Tel. (709) 772-4619.

K.G. Proudfoot
Acting Director

AGRONOMY

Forage crops

As part of the Atlantic Canada Cooperative Forage Evaluation Program, alfalfa, red clover, timothy, and four miscellaneous perennial grass cultivar trials were maintained at St. John's in 1988. New trials were seeded for phacelia and perennial ryegrass. Herbage yields in all trials were higher than normal because of a warm May and adequate summer rainfall. The meadow fescue cultivar Trader was again the highest yielding forage, with 1988 dry matter yields of 10.3 t/ha. Data from the cooperative trials were used to support the addition of the alfalfa cultivar 532 to the Atlantic Region recommended list.

Land drainage

In 1988 a project was initiated in cooperation with the Fredericton Research Station to evaluate subsurface drainage technology on mineral soils used for forage production in Newfoundland. Funding for the project is being provided under the Atlantic Livestock Feed Initiative Technology Enhancement Program. The objectives of the project are as follows: to demonstrate the installation capability of modern drainage equipment under typical on-farm Newfoundland conditions; and to determine the hydraulic performance characteristics of the systems under Newfoundland soil and climate conditions. Drainage sites have been selected and planned layouts have been prepared, with installation scheduled for the spring of 1989.

HORTICULTURE

Potato wart disease

Soil amendments. A variety of chitin-related chemicals were used as soil amendments in the greenhouse. Substances such as glucosamine or *N*-acetyl-D-glucosamine were observed to induce suppression of wart disease, as did a mixture of glucose and ammonium sulfate. The results, however, although encouraging, were not as consistent as those obtained with crab shell. In a field trial, crab shell obtained from Nova Scotia was applied as a band either above or below the tuber. The results ran counter to our experience with crab shell, with as much wart developing in the treated plants as in the check plants.

Germination. Using a citrate–phosphate buffer system with the addition of NaCl to physiological saline strength, a number of experiments were carried out with and without glucose, or with and without heat shock. Glucose appeared to stimulate the production of germination vesicles, but the level was very low. Slightly more success was obtained using a heat-shock system. In this, temperatures and times ranging between 10 and 100°C, and 3 and 30 min were used. In cultures that displayed vesicle production, germination increased quite dramatically at temperatures of 70, 80, and 90°C. These observations are being examined further, with the aim of developing a new means of assessing viability in the causal agent.

Bioassay. The nodal propagant system previously reported was used to explore the limits of the bioassay for *Synchytrium endobioticum*. Infection occurred at a density level of one spore in 10 g of soil.

Eradication. Greenhouse experiments carried out with crab shell and *Synchytrium endobioticum* indicated that spore level diminished with time. After 3 months, only 50% of the spores introduced to the amended soil could be retrieved. Further research in this finding is being actively pursued.

Potato breeding

Trials of the golden-nematode-resistant and wart-resistant selection N1051-1 have been completed. This white-fleshed blue-skinned selection produces tubers earlier than the Blue Mac cultivar. Yields have been similar to those of Blue Mac, but dry-matter content of tubers is higher. Seed stocks are being multiplied in order to have sufficient seed available in 1990, when application will be made to name and license this selection. Weather conditions during the growing season were ideal for the development of wart disease in the Avondale test plots. In a repeat test of 48 F84 selections, only two remained free of infection this year, and first-time evaluation of F85 selections from the Fredericton breeding program indicated that 49 selections of the 71 tested were susceptible. Among recently introduced cultivars, Somerset, Russet Norkotah, Norking Russet, Red Gold, Rose Gold, and Saginaw Gold were susceptible. Three European cultivars, Barbara, Nicola, and Certo remained free of infection, as did the U.S. cultivar Hampton and the Canadian cultivar Eramosa. Of 74 advanced selections from the St. John's breeding program, 61 remained completely free from wart disease, while slight infections were recorded on the 13 classed as susceptible. The most promising wart-resistant selection, N1323-24, produced very heavy crops of round white tubers, although dry-matter content of the tubers was disappointing. This and other resistant selections will be further evaluated in trials in 1989, as will the early selection F80014, which has remained wart-free in 3 years of test. Further crosses with parents known to be early maturing, and with resistance to common scab, were undertaken successfully. Attractively shaped tubers were obtained in greenhouse grown seedlings from crosses of Atlantic × Kennebec and Mirton Pearl × Wischip.

Vegetable production

Rutabaga breeding. The selection RST, developed from a cross of summer turnip and rutabaga, continues to remain substantially free from clubroot in plantings throughout Newfoundland and has been named Kingston. Several different seed lots of Kingston that had been produced by local growers for their own use were seeded in observation plots at St. John's. No major differences in disease susceptibility, color, or shape of roots were apparent at harvest. Rutabaga populations that incorporate clubroot resistance with tolerance to triazine herbicides and that have resistance to root maggot injury and turnip mosaic virus have been developed, and selection for commercial suitability is continuing. Material resulting from crosses of triazine-resistant Laurentian (A6) and Kingston have increased plant vigor and have larger root size than the A6 parent.

Root maggot control in rutabagas. Rutabaga transplants were established at St. John's and Wooddale to assess root maggot control obtained from single drenches of either Guthion or Dasanit applied before planting. Twenty millilitres of a solution of Guthion (2.5 g Guthion 50WP in 1000 mL water) or Dasanit (2.0 mL Dasanit 720EC in 1000 mL water) were administered, by syringe, around the stems of each seedling 2–6 days before transplanting to the field.

Damage from root maggot larval attack was least at St.John's. Infestation indices were reduced from 140 to 50 for treated plots at St. John's and from 169 to 95 at Wooddale. Yields of marketable roots from the four replicate 10-m single-row plots averaged 61.1 kg at St. John's and 25.5 kg at Wooddale for the Guthion treatment and 43.9 kg and 20.0 kg for the Dasanit treatment. Untreated plots yielded 9.1 kg and 3.2 kg at St. John's and Wooddale, respectively.

Celery. With the use of the cultivar Stokes Improved Utah 52-70, transplants were evaluated at spacings of 35 × 35, 30 × 30, 25 × 25, and 20 × 20 cm at the Peat Substation, Colinet. Weeds were controlled with black plastic mulch. Total yield increased and base diameter of the celery (average of wide and narrow sides) decreased as spacing decreased from 35 × 35 to 20 × 20 cm. At spacings of 35 × 35, 30 × 30, 25 × 25, and 20 × 20 cm, celery yields were 87, 95, 117, and 146 t/ha, respectively, and base diameter was 9.3, 8.5, 8.0, and 7.3 cm, respectively.

Cabbage. At the Peat Substation, transplants of the cultivars Houston Evergreen and Slawdena were compared at in-row spacings (50 cm between rows) of 40, 30, and 20 cm. Weeds were controlled with black plastic mulch. Head weight increased for both cultivars as spacing increased from 20 to 40 cm, but Slawdena produced larger heads than Houston Evergreen at each spacing. Marketable head weights at spacings of 20, 30, and 40 cm were as follows: Houston Evergreen (0.75, 0.87, 0.90 kg); Slawdena (0.80, 1.04, and 1.10 kg).

Machinery. Testing of a modified carrot harvester for use on organic soils was continued. A small plow point 100 mm in width was installed to loosen carrots and reduce the amount of soil lifted with them. This solved the problem encountered in 1987 and permitted carrots to be harvested equally well when planted on ridges or on flat ground. Samples of carrots harvested by the machine were grouped to include all carrots that would meet the size requirements of the Canada No. 1 grade. Of these, 12.7% were found to be unmarketable because of damage by the harvester. Further trimming was required for 29.1% of the sample, while the remaining 58.2% were correctly topped. A more detailed damage assessment is planned for 1989, along with a comparison with a commercial harvester.

The adaptation of a chain-type trencher for installation of subsurface drainage tubing in organic soils continued in 1988. Cleaning teeth installed in the chain improved the ability of the machine to excavate a trench in wet peat. However, some problems are still being encountered with spoil falling back from the sides of the trench. Alternatives to correct this problem will be evaluated in 1989.

Lowbush blueberry production

Management studies. An experiment was established at the Avondale Blueberry Substation in 1983 (rep 1, 2) and 1984 (rep 3, 4) to examine the effects of weed control as well as rate and timing of fertilizer applications on lowbush blueberry production. Treatments included factorial combinations of the following factors and levels: N (0, 60 kg/ha); P (0, 26.2 kg/ha); K (0, 49.8 kg/ha); timing (vegetative year, fruiting year); and herbicidal weed control (yes, no). Plots were burned every 2nd year using straw. Preliminary results indicate that weed control, N, and timing of application were the principal factors affecting production.

During 1984–1985, severe winterkill occurred. Flower bud kill averaged 80 and 53%, respectively, where herbicide was and was not used. Furthermore, yield of ripe fruit was 13% lower in herbicide-treated plots. Much less flower bud injury occurred in 1986–1987 when only 7% winterkill was recorded. In those years, herbicide without N increased yield of ripe fruit by 203%. Also, N with herbicide increased yield of ripe fruit by an additional 7% when applied in the vegetative year and by 31% when applied in the fruiting year. Yield of ripe fruit from herbicide-treated plots receiving N was 4614 and 6019 kg/ha, respectively, for vegetative and fruiting year applications. N increased berry weight only when applied in the fruiting year.

Weed control. In cooperation with other federal and provincial research facilities in the Atlantic Region, the herbicide Glean was evaluated at Avondale for the control of bunchberry (*Cornus canadensis*) in lowbush blueberry. Rates of Glean evaluated were 0, 13.33, 20.00, 26.67, and 33.33 g/ha. Spray treatments were applied on 10 May, before blueberry or bunchberry emergence, to recently burned land. No evidence of injury to blueberry plants was observed at any time during the season. On 3 October, stem samples were obtained from each plot to determine the effect of treatments on the stem density of blueberries and bunchberries. Glean did not significantly affect the stem density of blueberries at any rate tested. Bunchberry control at the lowest rate of Glean was minor, but it improved with increasing rate of application. At the highest application rate, the stem density of bunchberries was reduced by approximately 69%. The average stem density of bunchberries, with Glean at 0, 13.33, 20.00, 26.67, and 33.33 g/ha, was 521, 496, 333, 230, and 162 stems per square metre.

PUBLICATIONS

Research

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Miscellaneous

Choo, T.M.; Connolly, B.J.; Langille, J.E.; Drapeau, R.; Coulman, B.; Walton, R.B.; Bubar, J.S.; Goguen, B.; Madill, J.; Proulx, J.G.; Fairey, D.T. 1988. Marino red clover. Forage Notes 31:64–65.

Hampson, M.C. 1988. Control of potato wart disease through the application of chemical soil treatments: An historical review of early studies (1909–1928). EPPO Bull. 18:153–161.

Research Station
Charlottetown, Prince Edward Island

PROFESSIONAL STAFF

L.B. MacLeod, B.Sc.(Agr.), M.Sc., Ph.D., F.C.S.S.S.	Director
L.S. Thompson, B.Sc.(Agr.), Ph.D.	Assistant Director
B.Stanfield,[1] B.S.A., M.S.A., M.L.S.	Librarian
D.O. Northcott,[2] B.Sc.	Technology Development Program (ERDA) Projects Officer
L.E. Hurry[3]	Administrative Officer

Cereal and Soil

J.A. MacLeod, B.Sc.(Agr.), M.Sc., Ph.D.	Head of Section; Cereal and forage nutrition
A.J. Campbell, B.Eng., M.Phil.	Agricultural engineering
M.R. Carter, B.Sc.(Agr.), M.Sc., Ph.D.	Soil tillage
T.M. Choo, B.Sc., Ph.D.	Barley breeding
L.M. Edwards, B.Sc., M.Sc., Ph.D.	Soil management
U.C. Gupta, B.Sc.(Agr.), M.Sc.(Agr.), Ph.D., F.C.S.S.S., F.A.S.A., F.S.S.S.A.	Soil and plant micronutrients
H.W. Johnston, B.Sc.(Agr.), M.Sc., Ph.D.	Cereal diseases
R.A. Martin, B.Sc., B.Sc.(Agr.), M.Sc., Ph.D.	Cereal diseases
H.G. Nass, B.S.A., M.Sc., Ph.D.	Wheat breeding, cereal physiology

Forage and Beef

H.T. Kunelius, B.Sc., M.Sc., Ph.D.	Head of Section; Forage management
P.R. Narasimhalu, B.Sc., B.V.Sc., M.S., Ph.D.	Forage conservation and utilization
M. Suzuki, B.Sc., Ph.D.	Forage and cereal biochemistry and physiology
L.S. Thompson, B.Sc.(Agr.), Ph.D.	Forage and potato insects
K.A. Winter,[4] B.Sc.(Agr.), M.Sc., Ph.D.	Animal nutrition

Potato and Vegetable

J.A. Cutcliffe, B.Sc.(Agr.), M.Sc.	Head of Section; Vegetable nutrition and management
W.J. Arsenault, B.Sc.(Agr.)	Tobacco and potato variety evaluation
J.A. Ivany, B.Sc.(Agr.), M.S., Ph.D.	Weed control
J. Kimpinski, B.S.A., M.Sc., Ph.D.	Nematology
H.W. Platt,[5] B.Sc., Ph.D.	Potato diseases
J.B. Sanderson, B.Sc.(Agr.), M.Sc.	Potato management and fertility
J.G. Stewart, B.Sc., M.Sc., Ph.D.	Entomology
R.P. White, B.S.(Ed.), M.S., Ph.D.	Potato and corn nutrition and management

Departures

R.G. Andrew, B.Sc.(Agr.), M.Sc. Transferred to Agriculture Development Branch, October 1988	Agricultural economics
M.B. Bourdon, D.Journ. Resigned November 1988	Industry Relations Information Officer
L.J. Halliday, B.Sc., Ph.D. ERDA term expired	Forage degradation and quality
B.L. McFarlane, B.Sc.(Biol.), M.Sc. Resigned June 1988	Technology Development Program (ERDA) Project Officer
B.J. Murray Resigned December 1987	Administrative Officer

VISITING SCIENTIST

J.C. Li, B.Sc. The Biology Institute of Shanxi Province, Taiyuan, People's Republic of China	Barley tissue culture

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[1] Seconded from Libraries Division, Corporate Management Branch, Ottawa.
[2] Joined staff June 1988.
[3] Joined staff September 1988.
[4] Seconded to Research Coordination Directorate, Ottawa, June 1988 to June 1989.
[5] On transfer of work to Wageningen Agricultural University, Wageningen, The Netherlands, August 1988 to August 1989.

INTRODUCTION

The Charlottetown Research Station was established in 1909 on the outskirts of Charlottetown on 12 ha of land leased from the government of Prince Edward Island. Charlottetown was the second experimental farm (after Nappan in 1886) established east of Ottawa. By the 1940s the land base had increased to 60 ha, and by the 1960s the station had become encircled by the city. The Upton Farm (111 ha) was established in West Royalty between 1945 and 1953 and now accommodates the dairy-beef research program and most of the forage research. In 1983 the Harrington Research Farm (134 ha) was established and accommodates over 60% of the station's field plot research on livestock feed crops, potatoes, crop rotations, and soil management and conservation. In addition, 50 ha of land are rented from farmers across Prince Edward Island to meet specific research requirements.

The Charlottetown Research Station has a total staff of 102 person-years including 24 scientists, a total budget of $5.3 million, and an operating budget of $1.1 million. In addition, the station administers the following: 5-year technology development program under the Canada–Prince Edward Island Economic Regional Development Agreement (ERDA) ($4 million); 4-year alternative enterprises initiative program ($0.2 million); and contracted-in funds ($0.06 million annually). As well, the station plays a leading role in a 4-year Atlantic livestock feed initiative technology advancement program ($2.8 million). The research station administers several major research contracts with the Atlantic Veterinary College of Prince Edward Island University, Nova Scotia Agricultural College, Dalhousie University, Technical University of Nova Scotia, and Mount Allison University under the ERDA agricultural subagreement. Most of the Prince Edward Island Department of Agriculture staff are housed in the same building as Research Branch staff and work closely with scientists for transfer of technology to the industry.

The station has a mandate for breeding barley for eastern Canada and for breeding and management of other cereals and protein crops for Atlantic Canada. This work includes breeding of wheat and development and evaluation of oats, soybeans, and other protein crops such as lupins. The development of disease resistance and disease control procedures plays an important part in cereal management research as do crop sequencing or rotation studies.

The mandate of the soils group includes soil physics and engineering in relation to tillage: minimum tillage, direct drilling of cereals, and forage crops. Soil management and cropping practices are developed to minimize soil erosion, and the effect on groundwater quality is monitored. The micronutrient nutrition of livestock feed and of vegetable crops is studied.

In the forage and beef section, the emphasis is on the development of cost-effective feeding systems for dairy-beef. This work is supported by research on forages for pasture and conserved feed (including breeding of persistent clovers) as well as management, biochemistry, physiology, conservation, utilization, and pest studies of forages.

Research is conducted on potatoes, vegetables, small fruit, and tobacco, with emphasis on pest control, fertilization, and management practices. Charlottetown has a shared mandate with Fredericton for work on potatoes. Studies on potatoes include epidemiology, control of fungal diseases, fertilization, management, weed control, insect control, nematode population dynamics, and systems of production for small whole seed. Programs on vegetables and small fruit include fertilization, management practices, cultivar evaluation, and insect control. Tobacco selections are evaluated for regional adaptation.

This report includes brief summaries of some of the research completed in 1988. More detailed information may be obtained by referring to the station's research summary, which is published annually, or by contacting the Research Station, Research Branch, Agriculture Canada, P.O. Box 1210, Charlottetown, P.E.I. C1A 7M8; Tel. (902) 566-6800.

L. B. MacLeod
Director

CEREAL AND SOIL

Cereal breeding and management

Linearity of offspring–parent regression. A study was conducted to test the linearity of offspring–parent regression in barley. Forty-two F_2 families and 398 $F\infty$ (i.e. doubled-haploid) lines were derived from 7 × 7 diallel crosses. The F_2 families, $F\infty$ lines, and their parents were evaluated in hill-plots with five replications. Three types of regression analysis (regression of F_2 family on mid-parent, regression of $F\infty$ family on mid-parent, and regression of $F\infty$ line on mid-parent) were carried out for grain yield, heading date, plant height, and number of spikes per hill. The linear regression mean square was significant in most cases, but the quadratic regression mean square was not significant in all cases. These results suggest that the true regression of offspring on mid-parent is linear, although dominance, additive × additive epistasis, and maternal effects were detected for the four traits of the same materials in previous studies.

Doubled haploids. Molecular markers are useful for locating quantitative trait loci (QTLs). The current practice, however, of using molecular markers to locate QTLs in F_2 and backcross populations in plants has several limitations.

In contrast, these limitations do not exist if the marker-based analysis is carried out in $F\infty$ (i.e. doubled-haploid) populations. $F\infty$ lines can be evaluated under commercial production conditions in many environments; an unlimited number of molecular markers and quantitative traits can be studied in a given set of $F\infty$ lines; and the additive effects of marker-linked QTLs can be detected even in the presence of gene interactions among QTLs. Consequently, the usefulness of any molecular marker in a marker-assisted selection program can be determined without any follow-up studies. Therefore, it is recommended that molecular markers and doubled haploids be used together to study QTLs in diploid crop species such as barley.

Early yielding grain corn hybrids. New corn hybrids submitted for evaluation in six maritime regional grain corn trials showed considerable improvement in at-harvest grain maturity and some yield improvement between 1981 and 1987 in relation to the performance of standard check hybrids grown in all trials. After adjusting for changes in at-harvest maturity between 1981 and 1987, regression analysis indicated the average yield potential in 1987 had increased by 4.4%, or by about 0.2 t of dry matter per hectare. The improvement in maturity was, on average, 3.7%, representing a lowering of the actual at-harvest grain moisture content by 2.4% moisture, after adjusting for changes in yield between 1981 and 1987.

However, at a yield level of 4.6 t/ha of grain, representing 90% of the mean yield in 1987, the reduction in actual moisture content of the grain at harvest was 4.0% moisture. Even more significant, 16 of the 36 hybrids evaluated in 1987 were earlier in maturity than Euros LG3 (the earliest hybrid in the 1981 trials), and of the 16, 10 also yielded more than the 4.9 t/ha of grain produced by Euros LG3 in the 1987 trials. These findings demonstrate that some hybrids available in 1987 were not only considerably earlier maturing than those available in 1981 but also gave good yield levels equivalent to or better than hybrids available in 1981.

Cereal disease nursery. A cereal disease nursery was established in 1988 with the acquisition of a field-misting system. Within this nursery, foliar and head diseases of cereals were initiated following inoculation and moistening of the plants to begin disease symptom development. The system will be used in disease resistance breeding programs on oats and wheat for *Septoria* species and on barley for *Pyrenophora teres*. The nursery will be particularly useful for detection of resistance to fusarium head blight in all cereals, as early head symptoms develop rapidly, allowing a longer assessment period and reducing influence of host maturity.

Soil management and tillage

Soil macroporosity in moldboard plowing and direct drilling studies. The temporal variability of soil porosity, especially macropores (>50 μm), and associated porosity factors, such as pore continuity and percentage of water-filled pore space (%WFPS), were determined over 3 years under direct-drilling and moldboard plowing. The study was conducted on a Charlottetown fine sandy loam, an Orthic Podzol with a humid to perhumid soil-moisture regime. Differences in soil porosity between tillage systems were confined mainly to the surface 0–8-cm soil depth. The absence of soil loosening caused the volume of macropores to fall below 10% during the

growing season. Tillage had a residual effect on soil porosity, maintaining the volume of macropores at between 11 and 18%. In general, water-storage pores were similar between tillage systems. A close relationship (r^2 = 0.832) was observed between dry bulk density and macroporosity under both tillage systems. The relationship between macroporosity and pore continuity (K_{sat}), which differed between tillage systems, indicated that a macroporosity of between 8 and 10% (v/v) would maintain adequate soil permeability. In contrast, the %WFPS, which was closely related (r^2 = 0.952) to macroporosity and soil water content, indicated that the volume of macropores should exceed 14% to provide an optimum level of air-filled pore space. Under humid soil-moisture regimes, the use of macroporosity as an index of critical soil structure or limiting density needs to be based both on adequate soil permeability and on water-filled pore space.

Use of penetration resistance in tillage experiments. Soil penetration resistance was used to characterize tillage-induced changes in soil strength, as a function of soil depth and time, under three reduced tillage systems and a study on deep tillage in loam to fine sandy loam, Podzolic, and Luvisolic soils. The measurements of penetration resistance quantified the depth, degree, persistence of soil loosening, and potential soil rooting depth in regard to tillage system. Moldboard plowing provided a greater degree of soil loosening than chisel plowing. The potential soil rooting depth of 33–36 cm under moldboard plowing was decreased to 26 cm under both direct drilling and shallow tillage. Use of a slant-legged subsoiler (i.e., "paraplow") before direct drilling prevented the reduction in soil rooting depth. The depth of soil loosening gradually declined by 30 and 60%, over a 5-month period, under moldboard plowing and the paraplow direct-drilling system, respectively. Residual tillage effects and soil compaction after deep loosening were quantified by measurements of resistance to penetration.

Effect of direct drilling and soil loosening tillage systems for spring cereals. Changes in soil structure and properties, plant growth and diseases, and agronomic aspects were determined, after 3 years, on a Charlottetown fine sandy loam, subjected to three tillage systems for spring cereals. The tillage systems consisted of direct drilling, soil loosening with a paraplow, followed by direct drilling and moldboard plowing. Rate of plant growth and other crop measurements were not changed by the tillage systems, except for the depth of seeding. Direct drilling reduced the accumulation of N and K in the plant and reduced grain N, compared with moldboard plowing. Soil loosening before direct drilling prevented the decline in N and K accumulation, and increased grain yield and N content, in comparison with moldboard plowing. Direct drilling caused changes in soil macro-aggregation, reduced the evaporation rate, and increased microbial biomass C and N, total organic C and N, and extractable ions at the soil surface (0–5 cm), compared with moldboard plowing. In addition, earthworm numbers were increased under direct drilling. Root lesion and spiral nematodes were not influenced by tillage differences. Although soil permeability was optimum under direct drilling alone, the relative increase in relative water saturation and the reduction in soil aeration were associated with a concomitant increase in common root rot.

Performance of cover crops spring-seeded into standing winter rye and their relation to physical conditions of the soil. This study assessed, over a 3-year period, the cumulative dry-matter (DM) yield (as a measure of ground cover performance) of red clover and Italian ryegrass spring-seeded into fall-seeded winter rye using one broadcast and two drill-seeding methods. Yield of winter rye and changes in physical characteristics of the soil were also assessed. Yield of red clover was 48% more than that of ryegrass. However, the air seeder, which was the least compacting machine, afforded a 30–60% greater cover-crop yield than either of the other seeders. Underseeding the cover crops did not affect winter rye grain yield. In the year after cover-crop seeding, red clover showed a significant linear decline (r^2 = 0.66) with increasing soil penetration resistance, thus confirming the benefits of seeding with a low-compacting machine like the air seeder. Red clover also showed a significant quadratic relationship (r^2 = 0.70) with shear strength. Cover cropping is a standing recommendation against soil erosion in Prince Edward Island, particularly after potato cultivation, which would otherwise leave the soil compacted and bare during the cool season.

Effect of slope position and cropping sequence on physical properties of the soil. Physical characteristics of the soil were

examined at depth intervals of 0–15 and 15–30 cm over three slope positions (top, mid, and bottom slope) for three cropping sequences (hay–barley, cereals–barley, and potato–barley). Hydraulic conductivity (HC) was a significant 40–50% greater at top slope than at mid or bottom slope, and aggregate stability percentage (AgSt) was a significant 6–7% greater at bottom slope than at mid or top slope when the soil aggregates were pretreated by freezing and thawing (freeze–thaw). Under the potato–barley sequence, shear strength (VS), penetration resistance, and bulk density were significantly greater than any other sequence by up to 29, 21, and 15% respectively, whereas HC and maximum penetration depth were respectively up to 65 and 28% lower than any other sequence. Under hay–barley, HC and AgSt (freeze–thaw) were respectively up to a significant 82 and 10% greater than any other sequence. There was, therefore, significantly more compaction under potato–barley and more soil physical enhancement under hay–barley than other respective sequences. Disease severity was up to 55% greater at bottom slope than at mid slope or top slope for Birka barley, which also showed a significant linear decrease (r^2 = 0.89) in yield with increasing VS. Yield of Perth barley showed a significant linear increase with increasing soil depth (r^2 = 0.92) and clay–silt content (r^2 = 0.78).

Effect of freeze–thaw, soil compaction, and ground cover on soil erosion. Three Prince Edward Island soils (loam, fine sandy loam, and sandy loam) were tested under a laboratory rainfall simulator to examine the effects of freezing and thawing, winter rye cover, incorporated cereal residue, and subsoil compaction on runoff volume and sediment loss. Wooden soil boxes and ancillary collection frames (termed soil cassettes) were designed to be operated four at once in the simulator. Where the soil was frozen for 10 straight days, there was a significant 178% greater sediment loss and a 160% greater runoff than with daily freeze–thaw over the same period, but there was no difference in sediment concentration. Incorporated cereal residue afforded significantly better erosion control than winter rye, having decreased sediment loss to 50% and runoff to 77% of that for bare soil, whereas winter rye cover decreased sediment loss to 73% of that for bare soil. Soil compaction caused a 45% increase in sediment loss. Soil type had no effect on total sediment loss but significantly affected the movement of fine sediment fractions. For fractions <0.075 mm, the loam showed a 16.5% greater loss than the fine sandy loam, which showed a 23.4% greater loss than the sandy loam.

FORAGE AND BEEF

Red clover breeding. The Charlottetown breeding line CRS1 had higher yield and better winter survival than the two check varieties Florex and Prosper I on the basis of 8 location-years in the 1986 red clover regional trial. CRS1 red clover was supported by the Atlantic Advisory Committee on Forage Crops for registration in Canada.

Yields and quality of forage kale. Forage kale, *Brassica oleracea* L., is a high-yielding and frost-tolerant green forage crop suitable for grazing in the fall. The dry-matter yields and composition of Maris Kestrel kale were determined between 16 September and 6 December at 18- to 22-day intervals over 2 years. The dry-matter yields peaked at 10 166 kg/ha in early November and then declined at about 19 kg/ha per day. The in vitro digestibility of dry matter ranged from 916 to 952 g/kg among the harvest dates. Crude protein was similar for the harvest dates, averaging 105 g/kg. Cellulose, hemicellulose, lignin, and cell contents of kale varied inconsistently among the harvest dates. There was an increase in *S*-methylcysteine sulfoxide (SMCO) concentration of leaves from 1.4 to 6.2 g/kg between the first and last harvest dates. At these concentrations, SMCO was not high enough to predispose cattle that consumed daily up to 1.5 kg dry matter per 100 kg liveweight, to hemolytic anemia. The mineral composition of kale was adequate, with the exception of copper, manganese, and zinc, which would not satisfy the dietary requirements of ruminants.

Nutritive value of timothy–quackgrass silage. Dry-matter yield of timothy–quackgrass was about the same as that measured in a timothy stand. Quackgrass infestation of timothy decreased acid detergent fiber but had no effect on lignin or crude protein contents in the silage. Feeding trials with sheep showed that the timothy–quackgrass silage was equally well consumed and digested as the timothy silage. Forage yield and quality were concluded to be mainly unaffected when up to 56% of the stand of timothy was infested by quackgrass.

Boron deficiency and toxicity levels in crops. In plant tissue, B concentrations of less than 30 mg/kg in alfalfa and less than 20 mg/kg in red clover were related to B deficiency. In plant tissue, B concentrations of 105 and 90 mg/kg in alfalfa and red clover, respectively, were related to B toxicity symptoms on the foliage as the burning of older leaf edges. Boron deficiency in cereals was associated with B at less than 2 mg/kg in boot-stage tissue. Yield reductions caused by B toxicity were obtained when the boot-stage tissue B exceeded 80 mg/kg.

Selenium enrichment of cereals and forages. A 5-year field study conducted in Prince Edward Island at two locations showed that sodium selenite applied as a foliar spray, with Se at a rate of 10–20 g/ha, could enrich cereals and forages sufficiently to prevent Se deficiency in livestock in the Atlantic region of Canada. To produce the same Se levels in crops would require less Se in the form of selenate than when selenite is used. For maximum efficiency Se should be sprayed when the vegetation has covered most of the ground.

POTATO AND VEGETABLE

Potato

Growth model for predicting potato yields in Prince Edward Island. A 2-year project funded under the technology development program of the Canada–Prince Edward Island Agri-food Development Subsidiary Agreement evaluated and refined an Australian potato growth model for use in Prince Edward Island. Weekly potato yields, after tuber initiation, are predicted based on the following site-specific information: cultivar, emergence date, plant density, stems per plant, soil water deficit at planting, a management factor, weekly means of maximum and mimimum air temperatures, solar radiation, weekly totals for rainfall (including irrigation), and evaporation. The model recognizes five major physiological events (planting, emergence, tuber initiation, attainment of maximum bulking, and cessation of bulking) and relates these to a physiological time scale (p-time) based on both time and air temperatures. The higher the temperature the more rapidly p-time accumulates (within certain temperature limits). Cultivars differ in the p-time required for each crop event. The management factor has to be estimated based on experience, correlations of model predictions with experimental crop trials, information about production in specific fields, and level of management input of the producer. The model was refined to suit potato production conditions in Prince Edward Island by utilizing detailed crop information collected biweekly from 20 commercial Kennebec or Russet Burbank potato fields over 2 years. The refined model (PEI-TUBERS) predicted the yields of 19 Kennebec crops to within plus or minus 16% (5 t/ha) 95% of the time and the yields of 23 Russet Burbank crops to within plus or minus 17% (7 t/ha) 95% of the time.

Potato irrigation requirements as predicted by a potato growth model. A potato growth model refined for conditions in Prince Edward Island was used to predict yearly yields of well-managed crops of both Kennebec and Russet Burbank potatoes using Charlottetown's historical weather records from 1968 to 1987. Yields were predicted based on actual historical moisture conditions (no irrigation) and assuming ideal moisture conditions (irrigation available).

In only 2 years (1975 and 1987) were soil moisture levels low enough for predicted unirrigated yields to be significantly different from the 20-year mean yield of 50 t/ha. An average 16% total yield loss was predicted in 1975, and a 12% loss was predicted in 1987, the two driest years. The model predicted an increase in the average Kennebec yield from 47.5 to 49 t/ha with irrigation. The maximum predicted increase of 8 t/ha would occur only 1 year in 10. For Russet Burbank, irrigation would increase the long-term yield from 51 to 53 t/ha, with a maximum predicted increase of 10 t/ha occurring 1 year in 10. Assuming potatoes are priced at $88/t and irrigation operating costs at $138/ha, irrigation equipment would not have been economically viable for Kennebec crops. A maximum threshold investment cost of $233/ha could be justified for Russet Burbank based on yield improvements predicted by the model, assuming amortization of the equipment at 10% over 10 years. However, the model is unable to predict losses in tuber quality or the cullage of irregularly shaped tubers resulting from poor moisture conditions, a problem especially prevalent in the Russet Burbank cultivar. Additional expenses for irrigation equipment would be justified by such losses.

The effect of short-term cropping sequence on N requirement of Russet Burbank potatoes. The effects of previous cropping sequences on the N requirement of Russet Burbank potatoes were determined in 1986. The previous 2-year crop sequences were as follows: potato–ryegrass, barley–red clover, and potato–potato. Ammonium nitrate was banded at planting with N at rates of 0, 50, 100, 150, 200, and 250 kg/ha on each of the three different cropping sequences in four replications. Total tuber yields for the control treatment were 21.7, 35.7, and 22.1 t/ha for the potato–ryegrass–potato, the barley–red clover–potato, and the 3-year potato sequence, respectively. Maximum tuber yield was 46 t/ha and was not influenced by cropping sequences, but maximum yield required N at 220, 170, and 200 kg/ha, respectively, for the same three sequences. Growing conditions in 1986 were favorable for the development of tubers with shapes unacceptable for market. The weights of these misshapen tubers were 1.9, 3.3, and 10.9 t/ha for the barley–red clover–potato, the potato–ryegrass–potato, and the 3-year potato sequence, respectively.

Microbial control of Colorado potato beetle. An application of *Bacillus thuringiensis* var. *tenebrionis* (serotype 8a8b) SANDOX 418 I reduced populations of the Colorado potato beetle on potatoes and resulted in tuber yields similar to yields from plots treated with the pyrethroid insecticide deltamethrin. M-One (*Bacillus thuriengiensis* Berliner var. *San diego*) also showed promise as a biological control agent for potato beetles. Tank mixing the fungicides mancozeb or chlorothalonil with M-One did not significantly affect the efficacy of M-One against newly hatched potato beetle larvae.

Quackgrass control in potatoes with fluazifop. Quackgrass control with fluazifop with active ingredient (a.i.) at 0.25 and 0.5 kg/ha in the greenhouse was greatest with application at the two-leaf stage compared with the four- and six-leaf stages. Control was not affected by rhizome length, with similar control obtained for plants grown from 2- and 10-node rhizome pieces. Removal of quackgrass shoots at 6 or 24 h after treatment resulted in decreased control at application rates of 0.25 and 0.5 kg/ha. Fluazifop at 0.5 kg/ha controlled quackgrass treated at the four-leaf stage. The active enantiomer of fluazifop at half the rate of the racemic mixture controlled the quackgrass to the same extent. Fluazifop did not affect Russet Burbank potato yield.

Quackgrass control with glyphosate and additives. The addition of nonionic surfactants nonylphenoxylpolyethoxy ethanol at 0.1% of total spray volume (v/v), tallow amine ethoxylate at 0.5% (v/v), or oil concentrate at 1% (v/v) to commercially formulated glyphosate applied with a.i. at 0.25 and 0.5 kg/ha improved control of quackgrass—*Agropyron repens* (L.) Beauv. However, the improvement was not sufficient to provide an acceptable level of control of quackgrass. The addition of ammonium sulfate to glyphosate gave significantly greater control of quackgrass at all three rates of glyphosate. In one of the two experiments, control with glyphosate with a.i. at 0.5 kg/ha was comparable to that with glyphosate with a.i. at 1.0 kg/ha. The addition of any of the three surfactants to the ammonium sulfate and glyphosate combinations did not further enhance control.

Vegetable and small fruit management

Asparagus cultivar trial. A replicated cultivar evaluation trial was established at the Charlottetown Research Station in June 1981. The planting established well, came into production early, and the highest yielding cultivars (Lucullus Mid-Early, Aneto, Lucullus Late, Larac) produced 3000–4000 kg/ha in 1983–1986, inclusive. However, plant vigor and survival declined, and yields in 1987 and 1988 were low. Examination of the crowns at the end of the 1988 harvest season indicated the presence of *Fusarium* spp. and *Rhizoctonia solani*, and the trial was terminated.

Onion cultivar trial. A number of cultivars of onions were evaluated at the Charlottetown Research Station in 1988. Several matured by late September. Bullet and Norstar were the highest yielding. These cultivars also produced the highest yields in a similar trial conducted in 1987. Bingo, Super Apollo, Columbia, and Eskimo also performed well and are considered worthy of further trial. Evaluation trials have been conducted annually since 1971, and the results show that satisfactory maturity and yields were achieved in 13 of the 18 years.

Effects of added nitrogen and potassium on yield and storability of rutabagas. Field experiments were carried out at two different locations in Prince Edward Island each year for 3 consecutive years to determine the effects of added nitrogen and potassium on yields of rutabagas (*Brassica napobrassica* Mill.) and subsequent losses during a 6-month period in two storage regimes. Preseeding applications of nitrogen at 120 kg/ha compared with 40 kg/ha generally increased marketable yields by 10–12%. Similar applications of potassium at 180 kg/ha compared with 60 kg/ha had no effect on marketable yields. Mean weight losses from dehydration of rutabagas held for 6 months at about 2°C and 95% relative humidity and at about 5°C and 90% relative humidity were 5.2% and 10.8%, respectively, and were not affected by the nitrogen and potassium treatments. Also, the nitrogen and potassium treatments had no effect on the proportion of the rutabagas that remained in marketable condition during the storage period.

Black currant cultivar trial. The cultivars Ben Lomond, Ben Nevis, Consort, Magnus, and Topsy were established in a replicated trial on fine sandy loam soil in 1978. Plants were spaced at 1.5 m in rows 3 m apart. A grass sod, about 2 m in width, was established between the rows in 1980. Ben Lomond produced at the rate of 7.4 t/ha in 1988, with a mean berry weight of 1.03 g per berry. Ben Lomond produced the highest yield each year since 1984 and a mean yield of 6.0 t/ha for 1984–1988.

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Research Station
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[1] Seconded from Libraries Division, Corporate Management Branch.

INTRODUCTION

The Kentville Research Station was established in 1911 at the request of the Nova Scotia Fruit Growers' Association on land donated by the province. The current facilities consist of three farms that occupy a total of 264 ha of land area. A modern agricultural centre completed in 1981 provides office, laboratory, and controlled-environment facilities for research and regulatory staff of Agriculture Canada as well as housing special extension and advisory services of the Nova Scotia Department of Agriculture and Marketing.

Kentville's research mandate is the development of new technology to increase market opportunities for the horticultural and poultry sectors in the Atlantic region. Emphasis is placed on genetic improvement, integrated pest management, efficient production systems, and the development of innovative new technology for storage, handling, and processing. The operations of the Nappan Experimental Farm, one of the five original research establishments of Agriculture Canada, add a further dimension to the Kentville program through the farm's concentrated efforts to improve beef cow–calf and swine production systems.

The staff complement for the two centres is 131, supplemented by short-term appointees for the delivery of the various collaborative projects with industry organizations and universities. The total budget is approximately $7 million.

The research results reported herein are intended as an overview only of current research. More complete information may be obtained in the annual research reports of the two establishments by writing to Agriculture Canada, Research Station, Kentville, N.S. B4N 1J5, Tel. (902) 678-2171; or the Experimental Farm, Nappan, N.S. B0L 1C0, Tel. (902) 667-3826.

G.M. Weaver
Director

CROP PRODUCTION

Genetic improvement of lowbush blueberries. Between 1963 and 1980, approximately 1300 blueberry clones were selected from commercial fields or from families of seedlings developed in the breeding program. Currently, 200 selections remain in formal cultivar trials. Three trials fruited in 1988, containing 81, 63, and 19 clones. Yields were high, with several clones producing more than 1 kg per plant. Berry qualities were evaluated, with emphasis on firmness, appearance, and flavor. Clones of particular merit included 73-9, 73-10, 73-14, 73-22, and 83-6. The cultivar Fundy was outstanding in several characteristics and is highly recommended for the fresh market.

The effect of plant spacing on marketable yields of lowbush blueberry. In an attempt to demonstrate whether a double- or triple-row alternate planting of clones would fill in faster when compared with a standard single row, an experiment was set out in 1980 with three clones and cropped for five seasons. Initially, there were three successive harvests, followed by a mow–burn–sprout season (1985) and then two successive harvests. Increasing plant density significantly increased yields in the first two harvest seasons only, and the type of clone was the most consistent factor in determining a yield difference.

The effect of sawdust mulch and irrigation on marketable yields of the lowbush blueberry. Mulch alone significantly increased fruit yields in two out of three seasons, whereas irrigation was not an important factor for plant establishment and subsequent fruit yield.

Strawberry breeding. Fourteen strawberry seedlings were selected for further evaluation from a total population of 4600 seedlings. The cross Micmac × Honeoye was notable in that it produced five selections with large, glossy fruit exhibiting greater firmness than Micmac. The red-stele-resistant selection K83-4 (Glooscap × Annapolis) continued to demonstrate superiority over the standard cultivar Annapolis, both in yield and fruit size. In a trial of nine clones, K83-4 ranked third in marketable yield (23.6 t/ha) and first in seasonal fruit weight (15.1 g).

Raspberry breeding. A raspberry trial, established in 1986 to compare the standard cultivar Festival to four Kentville selections,

had its first crop in 1988. Selection K81-6 (combining genes from Muskoka, Ottawa Latham, Creston, and Willamette) performed very well, with a marketable yield of 9.9 t/ha and a seasonal fruit weight of 4.3 g. Festival ranked third in yield (5.7 t/ha) and fruit size (3.2 g per berry). The locally important disease, late yellow rust, has not been observed on K81-6; Festival is highly susceptible. Another selection showing particular promise in 1988 was K76-1, a genetically spineless clone.

Comparison of seaborne waste products with a commercial fertilizer on yield of broccoli, cabbage, and cauliflower. Transplants of broccoli, cabbage, and cauliflower received three rates of nitrogen (0, 75, 150 kg/ha) supplied by either 17–17–17, liquid fish silage, fish-bone meal, or seaweed meal and were grown under irrigation in a sandy loam soil. Marketable yields of broccoli were not significantly affected by either rate or source of nitrogen, whereas total marketable yields of cabbage and cauliflower from all fertilized plots were increased significantly compared with the no nitrogen treatment. Total yields and weight per plant yields for these two crops were affected by nitrogen source, with yields from plants receiving 17–17–17 and fish-bone meal being significantly higher than those from plants receiving liquid fish silage and seaweed meal. Depending on the economics of these seaborne products, some of them could be good alternatives to commercial fertilizer.

Fish-bone meal and liquid fish silage as alternatives to commercial fertilizer for the production of table beets. Studies were carried out with the red beet cultivar Ruby Queen, seeded to a Somerset sandy loam soil. All plots were irrigated and all fertilizers applied preplant at a nitrogen rate of 100 kg/ha.

The fish-bone meal was produced by grinding unwashed fish frames and contained approximately 7–8% sodium. The liquid fish silage was a product of cod or ground fish offal preserved in formic acid.

There is an indication that a preplant application of fish-bone meal containing a small amount of sodium will support beet yields equal to or greater than a commercial fertilizer or liquid fish silage. The addition of sodium chloride (up to 1000 kg/ha) tended to reduce the yield of marketable beets. Plants receiving the treatment of fish-bone meal produced the highest average weight per beet (in the >7.6 cm grade), indicating that beets given this treatment could have been harvested earlier than those given the other treatments, with a substantial increase in marketable yield (3.8–7.6 cm).

Effect of ancymidol of XE-1019 on growth and flowering in three asiatic hybrid lilies. Ancymidol (α-cyclopropyl-α-(4-methoxyphenyl)-5-pyrmidinemethanol) and XE-1019 (E-(*p*-chlorophenyl)4,4-dimethyl-2(1,2,4-triazol-1-yl)-1-penten-3-ol) have been evaluated for height control of the asiatic hybrid lily cultivars Prominence, Connecticut, King, and Enchantment. A single application of XE-1019 at 0.05 mg per plant effectively controlled height in all cultivars. Higher concentrations (up to 0.4 mg per plant) resulted in delays in flowering, reduced the number of flowers, and caused excessive limitation of stem length. Drench applications of XE-1019 at 0.4 mg per plant and ancymidol at 0.5 mg per plant also controlled height to acceptable values in each cultivar. The very low concentration of XE-1019 required to limit plant height is an advantage, but care must be taken not to exceed this rate or plant quality and earliness may be jeopardized.

Capillary irrigation of woody ornamentals: Effects of fertilizer type and placement. Dibbled application of Nutricote controlled release fertilizer (16–4.4–8.1 Type 140:40 applied in a 3:1 ratio) resulted in poorer growth of capillary-irrigated Andorra juniper as compared with the results achieved when the same fertilizer was incorporated in the growing medium or applied to the container surface. There were, however, only minor growth differences between application methods when another controlled release fertilizer (Osmocote 18–2.6–9.7) was used. Dibbled applications of Nutricote in all cases resulted in high levels of soluble salts in the medium in the early season, which tended to suppress growth of both root and shoot at a critical growth stage. Sarcoxie euonymus, on the other hand, showed no sensitivity to fertilizer placement or type, illustrating that growth response of woody ornamentals to these parameters varies significantly with species. These data do not, however, support the concept of dibble application of fertilizer in container culture.

Cereal cultivar testing. There were 52 cultivars of barley tested at Nappan in 1988. Of the two-row type, OB751-12 and OB751-27 have been supported for licensing. In the

six-row test, the Quebec barley QB198.27 was licensed as Chapais last year and included as a standard check cultivar. There were 21 spring wheat cultivars tested, and again Messier was the top cultivar. In 1988 two cultivars of the 22 tested were licensed. These were Perlo and Karat; both are milling wheats. Twelve triticale cultivars were tested and one cultivar, CT 3, has been supported for licensing.

CROP PROTECTION

Races of Phytophthora fragariae in Nova Scotia. Local races of *P. fragariae*, the causal agent of red stele root rot of strawberry, were identified on the basis of their virulence on the six indicator clones: Blakemore, Maryland 683, Sparkle, Stelemaster, Del Norte, and Yaquina A. Four races were found among 35 isolates collected from 19 commercial strawberry operations in Nova Scotia and one field plot at the Kentville Research Station during 1986–1988. Race A-6 was the most common race in the province, accounting for 31 (88.6%) of the isolates. Race A-4 was found at two sites (5.7% of isolates) and race A-7 at one site. A fourth race with a virulence pattern different from any of the 10 known North American races of *P. fragariae* was found at one site. Screening of strawberry germ plasm for red stele resistance at Kentville is being modified to reflect the results of the race identification study.

Resistance of Phytophthora fragariae to metalaxyl. Eighty-five percent of *P. fragariae* isolates from a Nova Scotia strawberry field where metalaxyl (Ridomil) had been used for several years to control red stele root rot showed some degree of resistance to the fungicide in vitro (EC_{50} values 0.52–102.33). In contrast, isolates from fields with little or no history of metalaxyl use were all sensitive to the fungicide (EC_{50} values 0.01–0.02).

Survival of sclerotia of Monilinia vaccinii-corymbosi in relation to pruning of blueberry fields by fire or mowing. Flail mowing of blueberry fields has become popular because it costs less than pruning by fire. However, concern has been raised regarding the likelihood of increased perination of *Monilinia vaccinii-corymbosi*, which causes monilinia blight. The pathogen produces sclerotia, which overwinter on the soil. A study to quantify the effects of mowing versus burning showed that mowing did not reduce the viability of sclerotia. Mowing generated significant amounts of debris, which covered the sclerotia and tended to protect them from fire during subsequent burns. Pruning by fire significantly reduced the viability of sclerotia, provided that they were not covered by debris from previous mowing. Mowing was concluded to result in increased levels of monilinia blight.

Characteristics and identity of bacteria associated with head rot of broccoli. Fluorescent pseudomonads were found to be the predominant microbes causing water soaking or decay of broccoli. Apart from pectolytic characteristics, a key factor in the etiology of head rot was the ability of some strains to wet the waxy surface of broccoli florets, which resulted in a water-soaked appearance. This effect was associated with surfactant-like activity of inoculum suspensions. Pectolytic, surfactant-positive strains identified as *Pseudomonas fluorescens* biovar II and IV were the most virulent of all strains examined. Nonpectolytic, surfactant-positive strains of these two biovars caused extensive water soaking, but no decay. Pectolytic, surfactant-negative strains of *P. viridiflava* and *Erwinia* spp. did not cause water soaking and were able to macerate only wounded tissues. However, when these strains were coinoculated with the nonpectolytic, surfactant-positive strains of *P. fluorescens* biovar II and IV, extensive water soaking and decay ensued. The surfactant characteristic appears to be a novel plant pathological trait and is essential for pathogenicity of some bacteria.

Computer model simulating chemical control of European red mite. A model was developed to simulate chemical control of the European red mite, *Panonychus ulmi* (Koch), in Nova Scotia apple orchards. Simulated densities of summer eggs and motile *P. ulmi* were similar to densities observed in experimental plots that had been treated with a miticide. The model was used to estimate the best dates to apply miticides with various biological half-lives (7 or 30 days) and specific toxicities. Criteria for effectiveness of a given application were as follows: cumulative mite-days to 15 July; yield per tree; and density of winter eggs on 31 August. The best dates to apply miticide differed according to the characteristics of the miticide and the criterion of effectiveness. The model also indicated problems in using the current economic

threshold based on counts of summer eggs and motile mites on leaves: if the initial population is moderate or high and the choice of application date is based on mite density on leaves, then application of miticide may be too late to prevent significant yield losses in the current year, a high population of winter eggs at the end of the season, and reduced return bloom and yield in the following year. The model suggests the importance of early spring assessments of winter egg density and the necessity of considering age structure of the mite population and characteristics of the miticide in selecting dates for application.

An isolating mechanism between Ixodes dammini and I. scapularis. In northeastern coastal North America, spring nymphs of *Ixodes dammini* have a longer premolt period than those of *Ixodes scapularis*, with the result that *I. dammini* late-fall adults enter breeding activity the following spring. Late-season *I. scapularis* nymphs are early absent. This difference in the nymphal premolt period is the isolating mechanism between the species, which, despite the constant transport of immature specimens on migratory birds, maintains their separation from *I. dammini* in the north and *I. scapularis* in the south.

Related to the late-fall development stages of *I. dammini* is the restriction of the species, including the disjunct populations on Cape Ann, Mass., and Long Point, Ont., to the coastal area within the 2.8°C average November–December isotherm. This requirement has prevented the establishment of *I. dammini* in Nova Scotia, although adults introduced as immature specimens on birds have been found.

Differential uptake and metabolism of ^{14}C-hexazinone. In a greenhouse trial, tolerant black chokepear, *Pyrus melanocarpa* (Michx.) Willd., had a 3.5-fold greater ED_{50} dosage than sensitive trailing blackberry, *Rubus hispidus* L. Uptake of ^{14}C-hexazinone (Velpar) from a nutrient solution was fourfold greater in blackberry than in chokepear, related undoubtedly to a twofold greater root-to-foliage ratio in sensitive blackberry. ^{14}C-hexazinone was metabolized to a number of hydroxylated and demethylated derivatives and two triones, in roots, stems, and leaves of whole plants over 48 h and in ^{14}C-hexazinone-infiltrated leaf disks and root sections over 24 h in both species. Although differences in metabolism between the two species were not dramatic, chokepear degraded more ^{14}C-hexazinone than blackberry, and general levels of ^{14}C-activity in plant parts decreased more with time in chokepear, suggesting cleavage of the ^{14}C-labeled triazine ring and loss of $^{14}CO_2$.

Effect of canopy and incorporation on metribuzin persistence in soils. The half-life ($t_{1/2}$) of metribuzin applied to a bare soil surface was calculated from fitted regression curves to be 3–7 days over four field tests. An artificial cover erected over a portion of the plots that provided protection from direct sunlight increased, on average, $t_{1/2}$ by threefold from 7 to 21 days. A shallow incorporation provided by raking the plots immediately after application increased the $t_{1/2}$ twofold, compared with incorporated applications. In contrast, the differential canopy provided by planting soybeans at either 20- or 60-cm row spacings had no measurable effect on persistence over 60 days. The results suggest the photo-decomposition and volatility losses that have been previously measured in the laboratory must also influence metribuzin under field conditions. If so, the method of application and conditions soon after application should be important considerations when attempting to predict or assess metribuzin carry-over problems.

The effect of the herbicide clopyralid (Lontrel) on strawberries and its residues in fruit. Clopyralid was tested in early bloom, at renovation, and in the fall on several cultivars. Clopyralid at rates to 0.3 kg/ha in early bloom induced some injury, which was acceptable, and resulted in up to 10% yield loss in clean fields. These treatments provided excellent control of tufted vetch, goldenrods, Canada thistle, and others. Veestar was more sensitive than Kent or Honeoye. Residue levels ranged from about 50 to 370 ppb in fruit of the first harvest of plots treated during early bloom with clopyralid at 0.1–0.3 kg/ha. Little or no injury was observed with the same rates with renovation applications or those made on 28 September or 17 November. Residue levels in fruit from this trial ranged from not detectable to 3.1 ppb. Applications at these times of clopyralid at 0.1 and 0.2 kg/ha also provided excellent control of sensitive species, except ox-eye daisy, which required clopyralid at 0.3 kg/ha for good control.

Antagonistic effects of 2,4-D and bentazon on control of wild oats with tralkoxydim. The ED_{50} dosage of tralkoxydim on wild oats increased more than fivefold when tank-mixed with either 2,4-D amine or bentazon at 1.25 kg/ha. Short-term sequential spray applications and selective application of 0.2-µL droplets of herbicide solution indicated that bentazon antagonism occurred only where the two herbicides were mixed in the same droplet and probably resulted from reduced uptake of tralkoxydim into the leaf. 2,4-D antagonism occurred regardless of whether each component was applied as separate droplets or translocation of tralkoxydim to the meristem was ordered.

FOOD PROCESSING

Modified atmosphere packaging of wild blueberries. Storage of conventionally packaged produce at 0°C imparts short-term quality advantages similar to the modified atmosphere packaged (MAP) samples stored at 5°C. Moisture loss is, however, a limiting factor, making MAP a more attractive alternative for extended storage. The greatest benefits in quality maintenance were obtained by combining MAP with 0°C storage, irrespective of packaging format, making this the optimum storage and distribution system.

Fresh lowbush blueberry quality: problems induced by primary processing, handling, and storage conditions. Increasing the drop distance (damage) or storage temperature resulted in progressively more split berries, softer berries, loss of bloom, increased anthocyanin leakage, higher numbers of microorganisms, and a general reduction in marketable product. The magnitude of deterioration was greatest at the higher storage temperatures. Berries held above 0°C showed more decay and greater weight loss. Color change was also evident as damage to the fruit increased.

Little benefit was realized by precooling to 5°C. Preconditioning to 20°C before processing and storage resulted in reduced bloom loss, splitting, and a brighter berry color.

Washing was significantly detrimental to fruit quality following storage at all four temperatures.

The sensory assessment of strawberry cultivars. Eleven strawberry cultivars were presented to a trained sensory panel for the purpose of generating a profile of descriptive and distinguishing features.

Cultivars varied with respect to the sensory attributes of redness, glossiness, seedy appearance, texture, firmness, juiciness, pulpiness, aroma, sweetness, tartness, bitterness, astringency, flavor intensity, and specific flavors. Use of these profile elements enables a comprehensive description of each cultivar, provides a basis for comparing new selections to standard cultivars, and permits the establishment of a data base for relating sensory perceptions either to the physical and chemical properties of the berries or to indicators of consumer acceptance.

Modified atmosphere packaging of broccoli florets and shredded iceberg lettuce. A retail package system was used to study the atmosphere modification that developed in packages of shredded iceberg lettuce and in broccoli florets sealed in trays with a range of polymer films of various gas permeabilities. Modified atmospheres were produced both naturally (by respiration) and by application of gas flushing techniques.

With shredded iceberg lettuce an equilibrated atmosphere containing 1–3% O_2 and 5–6% CO_2 was established with 35-µm low-density polyethylene film after flushing with 5% O_2 and 5% CO_2 in N_2. This resulted in a shelf-life of approximately 14 days at 5°C, almost double that of the controls.

A 2–3% O_2, 2–3% CO_2 equilibrium modified atmosphere (MA) was established using LF film to package broccoli florets when stored at 5°C, but this did not markedly improve the quality of florets when compared with broccoli stored in air. When florets were packaged with films that resulted in very low O_2 atmospheres (1% or less) foul off-odors shortened storage life.

Shelf-life extension of fresh pasta using modified atmosphere packaging. Samples of fresh pasta were prepared to contain various levels—0.2–0.6% (δ/δ)—of the acidulant–humectant glucono-δ-lactone (GDL), packaged in a high-barrier film (DuPont Sclairfilm LP 920) and evacuated and flushed with CO_2:N_2 gas mixtures containing 25, 50, and 75% (v/v) CO_2, respectively. Representative packages were subsequently stored at 0, 5, and 10°C, respectively, and were periodically analyzed for their content of bacteria, yeast, and mold.

Unlike refrigerated aerobically packaged fresh pasta, where spoilage is caused primarily by molds and aerobic bacteria, the MA-packaged products were eventually spoiled by members of the bacterial family Lactobacillaceae, but only when the initial CO_2 concentration within the package met or exceeded 50%. Spoilage of the pasta was also delayed. In the presence of 50–75% CO_2, shelf-life was extended to 45 days at 5°C and to more than 60 days at 0°C. However, no significant shelf-life increase could be attributed to the addition of the GDL. Finally, temperature abuse (10°C storage) negated most of the positive effects of using MA packaging, thus emphasizing the requirement for good temperature control during distribution and retail if the benefits of this recently introduced technology are to be fully realized.

Alternative methods of juice clarification. Two alternative methods of juice clarification, ultrafiltration and centrifugation, were evaluated in comparison with the conventional sedimentation and diatomaceous earth (de) filtration procedure. Both offered potential advantages through the use of semicontinuous versus batch processing, reduction in material costs (de and enzymes), and improved product quality. Preliminary tests were conducted on a continuous centrifuge to determine the predominant factors affecting the rate and extent of clarification. Increased duration of storage caused an increase in the sediment volume and a reduction in the clarification efficiency of juice made from air-stored apples. Enzymatic treatment of either the juice or the mash increased the clarification efficiency, though the mash treatment was preferred for its increased juice yield.

Hard cider production from apples grown in Nova Scotia. Preliminary fermentation trials have been conducted on a total of 57 cultivars of apples to test their suitability for producing high-quality ciders and to define the processing conditions most suited to locally grown produce. Fermentation variables tested included method of sulfiting and depectinizing the raw juices; rate of amelioration with cane sugar, yeast strain, fermentation, and end-point; filtration and carbonation procedures; and length of maturation.

In general, the most consistently acceptable cider quality was achieved by sulfiting the juices immediately after pressing at a rate dependent on the pH of the juice, depectinizing with Kleerzyme 200, amelioration of each juice to an initial soluble solids of 16°Brix, fermentation with *Saccharomyces uvarum* at 18–20°C to a final soluble solids of 6–8°Brix, cold-sterilizing filtration, bulk-tank carbonation using an overpressure of 138 kPa of CO_2 at 0–2°C for 24 h, crown-cap bottling under refrigerated conditions, and storage for at least 6–9 months at 15°C.

FRUIT AND VEGETABLE STORAGE

Effect of carbon dioxide, oxygen, and temperature in larvae of the lowbush blueberry fruit fly, Rhagoletis mendax. The presence of *Rhagoletis mendax* larvae in lowbush blueberry fruit reduces fruit quality and stops the shipment of fresh fruit to destinations outside the Maritime Provinces, where this insect does not occur. Since the fumigant methyl bromide is not registered for blueberries, and carbon dioxide is being successfully used for insect control in stored grain, the effect of carbon dioxide on *Rhagoletis mendax* larvae was examined.

The lower oxygen concentration (5%) was slightly more effective than the higher concentration (20%) regardless of temperature or carbon dioxide concentration. The carbon dioxide concentration had a significant effect, especially at the warmer temperature. Predicted mortality from the regression model indicated that the highest mortality would be obtained at 21°C, 5% O_2, and a CO_2 concentration between 40% (57% predicted mortality) and 60% (43% predicted mortality).

Effect of carbon dioxide on blueberry fruit fly larvae within the fruit of the lowbush blueberry. Fumigation with carbon dioxide had an effect on larvae within fruit, with the maximum effect occurring with concentrations of more than 90% for at least 48 h. This combination could produce larval mortality of more than 85%. Further research is needed to consistently achieve mortalities approaching 100%.

Postharvest quality of lowbush blueberry clones. Fruits of 10 lowbush clones were evaluated for postharvest quality after being held for 3 weeks at –0.5 and 3°C.

After 3 weeks at –0.5°C, all 10 clones had marketable berries, ranging from 59% for

75-21 to 100% for 73-22, with a mean of 81%. In the 3°C treatment, only five clones had marketable berries, with a mean of 41%. There were five clones that had superior marketability in the –0.5°C treatment—Brunswick, Chignecto, Fundy, 73-14, and 73-22. Clone 73-22 had 100% marketability at both temperatures, but the berries had a tendency to split when handled. Fundy had the best general rating because it retained high soluble solids, titratable acids, and firmness at both temperatures.

Modified atmosphere fruit coating. Clapp's Favorite pears stored in 1.0 or 2.0% O_2 controlled atmosphere (CA) or dipped in 1 or 2% Nutri-Save and stored in air were firmer and retained higher titratable acids contents than the air controls after 120 days. Pears stored in 1.0 or 2.0% oxygen or treated with 2% Nutri-Save were the firmest fruit after storage. Fruit stored in 1.0% O_2 had significant levels of flesh breakdown resulting from low-oxygen injury, whereas pears stored in 2.0% oxygen had a high incidence of decay. Fruit treated with either 1.0 or 2.0% Nutri-Save showed the lowest incidence of flesh breakdown and decay. Apples treated with 1 or 2% Nutri-Save after harvest were firmer and had higher titratable acid retention when removed from storage than that of controls. Apple juice quality was improved and the level of relative ambient humidity was an important factor.

Water-vapor barrier for horticultural crops. Of the water-vapor barrier coatings formulated and applied to carrots, rutabagas, or English cucumbers, none were as effective as stretch film wrapping or 0°C storage (carrots or rutabagas) in reducing weight loss, retarding senescence, or preventing decay. The present study indicated that stretch film wrapping was the most effective moisture barrier tested. However, the study also suggested that individual commodities may require moisture barrier film formulations compatible with the cuticle specific to that commodity.

Storage of fiddleheads. Storage of ostrich ferns (fiddleheads) at temperatures above or below 0°C decreased storage life and marketable quality. Percentage of weight loss, ascorbic acid content, bacterial load, yeast, and mold loads generally increased, and relative water content decreased, with increased storage temperature above 0°C and duration. Absolute moisture and ascorbic acid content of fiddleheads decreased with extended storage at lower storage humidity. Marketable yields decreased with higher storage temperature, lower storage humidity, and extended storage duration. Optimum storage conditions of 0°C and 100% relative humidity provided marketable yields of 95 and 76% after 16 and 32 days, respectively, whereas fiddlehead storage in H_2O and 0°C for 15 days provided marketable yields of 97%.

POULTRY

Performance comparisons of phased protein dietary regimens fed to commercial Leghorns during the laying period. Experiments with 2824 female Leghorn hens were conducted to estimate the effects of single-, double-, and triple-phase feeding regimens chosen from three isoenergic diets with either 15, 18, or 21% protein. The Leghorn genotypes were found to be adaptable to a wide range of feeding regimens, without extreme adverse effects. The quantity of feed required to produce 672 g of eggs was reduced significantly among hens fed diets with the higher protein content, but the consumption of protein, lysine, and methionine or methionine plus cystine per 672 g of eggs produced was significantly greater for these hens than for hens fed the dietary regimens containing lower protein. Feeding either an 18% protein diet to 210 days followed by a 15% protein diet from 211 to 490 days, or an 18% protein diet throughout the laying period, consistently supported performance that was equal to or better than other dietary treatments.

Omega-3 fatty acid levels and performance of broiler chickens fed redfish meal or redfish oil. Arbor Acre broiler chickens were fed six different diets to determine if the omega-3 fatty acid content of broiler chicken carcasses could be enhanced by feeding additional redfish meal (RFM) or redfish oil (RFO). The six diets were: control (no fish meal or fish oil), 7.5% RFM, 15.0% RFM, 30.0% RFM, 2.1% RFO, and 4.2% RFO. Mortality at 28 days and 42 days was lower ($P < 0.05$) for birds fed RFO compared with those fed RFM. Feeding additional RFM or RFO had no ($P > 0.05$) effect on mortality but resulted in lower body weights, lower feed consumption, and poorer feed conversion. Additions of RFM or RFO to the diets resulted in a substantial dietary enrichment of omega-3 fatty acids (especially eicosapentaenoic acid, EPA or 20:5*n*-3, and docosahexaenoic acid,

DHA or 22:6*n*-3). Analyses (w/w%) revealed that breast meat was lower in lipid and triglyceride but higher in cholesterol esters, free cholesterol, and phospholipid than was thigh meat. Lipid, free cholesterol, and phospholipid of edible meat lipid increased with duration of feeding, but triglyceride content decreased. Dietary treatment had no effect on carcass lipid content or composition. Breast meat lipid contained more of the omega-3 fatty acids and more total *n*-3 polyunsaturated fatty acid (*n*-3 PUFA) than thigh meat lipids. Eicosa pentaenoic acid (EPA), docosapentaenoic acid (DPA), docosahexaenoic acid (DHA), and total *n*-3 PUFA in edible meat lipids increased with duration of feeding. Feeding additional RFM and RFO resulted in an increased accumulation of EPA, DPA, DHA, and total *n*-3 PUFA, primarily at the expense of the omega-6 fatty acids, linoleic (18:2*n*-6) and arachidonic (20:4*n*-6). It can be calculated from the data presented that on average a normal meal (100 g) of chicken that has been fed 7.5% fish meal would contribute 140 mg of omega-3 fatty acids (EPA + DPA + DHA). A meal of the same size consisting of cod flesh would contribute about 135 mg of these fatty acids.

The response of male broiler chicks to the consumption of low levels of chlortetracycline as a growth promoter. A total of 3200 male broiler chickens were used to evaluate the efficacy of chlortetracycline (CTC) as a growth promoter when used in compliance with the present maximum feed-supplementation rate permitted in Canada (5.5 mg/kg). No significant ($P > 0.05$) improvements in 21- and 42-day live-body weights or feed conversion efficiencies were observed, regardless of the method of administration (feed or water). Changes to the sources of dietary calcium and phosphorus in an attempt to circumvent antibiotic inactivation by divalent cations also failed to potentiate any effect of this level of CTC. If adequate attention is paid to the diet and health of broiler stocks, no further gains will be realized through feed supplementation with CTC at 5.5 mg/kg.

Nutritive value of wheat screenings as a feed ingredient for broiler chickens. The effects of feeding diets containing 0, 15, 30, or 45% ground wheat screenings (WS) were assessed. Mortality was significantly higher for males than for females at both 21 and 42 days of age. Although there was no significant difference between feed conversion ratios for the two sexes, body weights were significantly higher for males than for females. Significant dietary effects were evident for feed conversion to 21 days of age but not to 42 days. Dietary effects on body weights were not significant, although a significant linear pattern at 21 days indicated that heavier weights were associated with higher dietary WS levels. Evidence is provided that satisfactory performance can be attained with diets containing up to 45% WS.

The nutritive value of triticale as a feed ingredient for broiler chickens. Five experiments involving 10 080 chickens were used to evaluate the effects of feeding diets containing 0, 15, 30, and 45% triticale. The diets were calculated to be isoenergic and isonitrogenous. The effect of using supplementary lysine in diets having escalating levels of triticale was included in these studies. Mortality did not differ significantly among dietary treatments. Dietary effects on feed conversion were inconsistent with two experiments providing evidence of a significant depression in feed efficiency associated with feeding triticale up to 21 days of age, but results from the other three experiments showed no detrimental effects. Body weights tended to be depressed with the higher dietary levels of triticale, which was particularly evident at 21 days of age, but supplementing starter diets with lysine did not correct this problem. Evidence indicates that growth inhibition associated with triticale limits its practical use to not more than 15% in broiler chicken diets; furthermore, damp litter conditions were also associated with the 30 and 45% dietary levels.

Effect of ambient temperature and dietary energy on the performance of turkey broilers. Performance of male and female turkey broilers was compared for up to 93 days of age when the birds were housed in one of three ambient temperature environments and fed one of four dietary regimens differing in energy levels. Feed conversion ratios were improved in the high-temperature environment, but feed intake and body weights were reduced. Higher dietary energy levels resulted in improved feed conversion ratios and heavier body weights except for the dietary regimen with the highest energy level. Temperature × dietary energy and sex × temperature × dietary energy interactions for body weights and feed conversion indicated that the dietary energy requirement may have been reduced in warmer environments, particularly for females.

NAPPAN EXPERIMENTAL FARM

Beef

Carrot silage. A mixture of culled carrots and chopped hay (3:1) was ensiled and fed to 40 growing cattle along with three other silages. The cattle grew at a rate of 0.72 kg/day during the 140-day feeding trial, equivalent to gains observed with our best brome–alfalfa silage. Supplementation with 1 kg/day of barley improved gains in both cases to 0.95 kg/day. The carrot silage had an in vivo digestibility of 63 for both dry matter and protein. Our results show that this mode of storing and feeding culled carrots can result in good cattle performance.

Postcalving nutrition of beef cows. A 2-year study was completed to evaluate the reproductive performance of 144 cows that were in low or good body condition at calving and that were fed silage with or without 4 kg of barley postcalving. Results indicated that the pregnancy rate, and days to breeding and to first heat, were much improved by feeding grain after calving, even with cows in good body condition. Grain feeding was also important to secure better preweaning gains. Higher body condition scores had no effect on birth weights of calves but did result in better reproductive performance.

Swine

Ensiled poultry offal as feed for swine. Diets containing as much as 10% (DM) ensiled poultry offal (EPO) in diets for growing pigs result in growth performance, feed conversion efficiency, and carcass quality equal to that of conventional diets. Bacterial culture of EPO revealed no presence of *E. coli* or salmonella.

Effect of hull-less oats on carcass quality of swine. Diets containing levels of hull-less oats as high as 95% can be fed to growing pigs with no detrimental effect on carcass quality or growth rate when removed from the diet at 60 kg liveweight. No removal of hull-less oats results in poor carcass quality, whereas removal at 80 kg results in poor growth performance in general.

Pigs modify their environment according to air temperature. When housed in unheated facilities, pigs spend significantly more time in an insulated hut when air temperature is below 4°C. Use of huts appears to be correlated to animal size as well as to temperature, with larger pigs using the huts less frequently than smaller pigs.

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Research Station
Fredericton, New Brunswick

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Departures

C. Esau, B.Sc. Resigned May 1988	Forage engineering
A.E. Fillmore, B.Sc., M.Sc. Resigned August 1988	Cereals
E.M. Tremblay-Deveau, B.Sc., M.Sc. Transferred to Potato Breeding Section, January 1988	Postharvest handling of fruit
L. Woodrow, B.Sc., M.Sc. Transferred to Harrow Research Station, September 1988	Physiology winterhardiness

VISITING SCIENTISTS

H. Owen, B.Sc., M.Sc., Ph.D. Visiting fellow, Natural Sciences and Engineering Research Council, departed October 1988	Potato tissue culture
F. Loiselle, B.Sc., M.Sc. Postgraduate student	Quantitative genetics and plant breeding

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[1] On transfer of work at Institut National de la Recherche Agronomique, Rennes, France, from August 1988 to July 1989.
[2] Seconded from Libraries Division, Corporate Management Branch.
[3] Completed education leave at Pennsylvania State University, University Park, Penn., August 1988.
[4] Appointed under Canada–N.B. Agri-Food Subsidiary Agreement 1984–1988.
[5] On education leave at Université de Paris XI, Paris, France, from December 1987.
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INTRODUCTION

The Fredericton Research Station traces its origin to the establishment in 1912 of the experimental farm on the eastern outskirts of the city of Fredericton. This was one of several experimental farms being established at the time by the Experimental Farms Service of the Canada Department of Agriculture. That same year also saw the establishment of an entomology laboratory on the campus of the University of New Brunswick by the Science Service of the Department of Agriculture. In 1915, the Science Service also established a plant pathology laboratory in downtown Fredericton. These three establishments were amalgamated in 1959 to form the Fredericton Research Station, within the newly formed Research Branch of Agriculture Canada.

The research station currently enjoys the advantage of having the head offices of the New Brunswick Department of Agriculture located in the same building on the grounds of the station. The Veterinary Inspection and Agricultural Inspection divisions of the Food Production and Inspection Branch of Agriculture Canada are also housed in this building. The fact that these agencies occupy the same building provides opportunities for close collaboration and effective communication among the several groups of employees serving the agricultural industry in various capacities.

The station operates a potato breeding substation at Benton Ridge, N.B., approximately 100 km west of Fredericton. This location was established in 1975 to provide isolated plot land for the breeding program, which would minimize the possibility of disease transmission within the breeding program.

The station also oversees the operation of the Senator Hervé J. Michaud Experimental Farm, established in 1978 near the town of Bouctouche, N.B.

The major areas of research activity at Fredericton include the national potato breeding program for Canada, research on the management of pests of the potato crop, and nutrition of dairy animals. Smaller research programs are directed toward the development of improved potato harvesting equipment; tissue culture and propagation of potatoes; nutrition of beef cattle; fertility, management, and conservation of soils; evaluation of cereal cultivars; and management and agronomy of forage crops, tree fruits, and small fruits. These research activities were augmented by a technology development program under the Canada–New Brunswick Agri-Food Subagreement, with additional in-house and contracted research on the livestock industry, livestock feed, and horticulture. Research at the Senator Hervé J. Michaud Experimental Farm serves mainly the horticultural sector of the province, with particular attention to the coastal region, performing evaluation of crop cultivars, and conducting experiments on management practices for vegetables, berries, and tree fruits, as well as participating in the cereal and forage programs of the station.

The land base for research activities at the three locations comprises 300 ha at Fredericton, 345 ha at Benton Ridge, and 28 ha at Bouctouche. Resources devoted to operation of the Fredericton Research Station and the Benton Ridge Substation during the 1988–1989 fiscal year included an operating budget of $1 240 000, a capital budget of $455 000 for both equipment and minor construction, and a staff complement of 112.4 person-years, including 24 professional staff. Resources for the Senator Hervé J. Michaud Experimental Farm included an operating budget of $76 000, a capital budget of $115 000, and a staff complement of 10.8 person-years, of which three are professionals.

The results reported herein provide an overview of some of the continuing research programs. Additional information may be obtained from the Research Station, Agriculture Canada, P.O. Box 20280, Fredericton, N.B. E3B 4Z7; Tel. (506) 452-3260.

D.K. McBeath
Director

POTATO BREEDING

Raw city water as a source of contamination of stock plants for tissue culture. Serious contamination of stock plants of the potato cultivars Shepody and Yukon Gold (*Solanum tuberosum*) for tissue culture was observed. Stem explants excised from these stock plants and placed in nutrient media exhibited 100% contamination. Filter sterilization of the raw city water, with which the greenhouse stock plants were irrigated, reduced the contamination of the cultures 30%. The bacterial flora isolated from the contaminated stem explant cultures was very similar to the flora observed from the residue in a pleated filter through which 50 L of raw city water had been filtered. Revising the excision procedures included transporting explants from the greenhouse to the laboratory in sterile water rather than tap water and cutting stems with sterilized blades. The use of raw city water on greenhouse plants and incorrect laboratory techniques can be important sources of contamination of cultures and test plants used for the identification of bacterial pathogens.

Potato breeding—Guelph. Two seedlings, F72217, named Eramosa, and MS002-171Y, named Saginaw Gold, received full registration status from Agriculture Canada in 1988. Canadex fact sheets for each have been published and circulated. Eramosa is a white-skinned, white-fleshed cultivar that has shown promise as a first early type, often producing marketable yields in 75 days from planting. Saginaw Gold (pale yellow flesh) is a main-crop cultivar for potato chips and table stock. It has consistently produced high-quality potato chips after tuber storage. Saginaw Gold was bred in Michigan and selected at Guelph and is being jointly released by Michigan State University, Agriculture Canada, University of Guelph, and Ontario Ministry of Agriculture and Food.

Breeding for potato chipping quality. Selection for good clones for potato chipping is often conducted during the middle and late breeding stages because of the resources needed for the assessment of several characteristics. Objective multivariate methods for the elimination of redundant variables were applied to eight traits of potato chipping quality, recorded on advanced clones. A reduction of the number of variables from eight to four could recover more than 80% of the original variations, showing that redundant variables were effectively discarded. The results reveal that specific gravity and direct potato chipping from the field were always retained. Reconditioning results from 1 and 4 weeks after cold storage were shown to be the most redundant variables.

Combining ability analysis of 4x–2x crosses. A new breeding method of crossing tetraploid potato cultivars with enhanced diploid germ plasm (4*x*–2*x* crosses) is currently being implemented. This method provides access to a large pool of *Solanum* germ plasm while allowing for hybrid vigor.

Information on general (GCA) and specific (SCA) combining abilities are important in determining appropriate breeding strategies for generating useful 4*x*–2*x* crosses. To evaluate the combining abilities of 2*x* parents, a group of 4*x* parents are chosen as testers. Each member of the 2*x* parents is used to cross with each of the 4*x* testers. Progenies are tested in the field. A mathematical procedure has been developed to resolve the problem of missing progenies (resulting from fertility or incompatibility problems between certain cross combinations). A field experiment involving 45 crosses obtained from ten 2*x* parents and five 4*x* testers was conducted in 1987 and 1988 at the Benton Ridge Potato Breeding Substation. The 2*x* parents were evaluated by their mean effects and sensitivity measures to the 4*x* testers based on the new method of analysis. The 4*x* parents were also evaluated by their tester effects. The analytic results fit the observed data very well. The results are used to identify superior 2*x* parents (high mean effect) or 4*x*–2*x* crosses (2*x* with above average mean and high sensitivity and 4*x* with high tester effect).

Response of cultivars to moisture stress. A joint study was conducted with the Lethbridge Research Station to determine the response to moisture stress of eight potato cultivars at three growth stages. Important differences were found between cultivars. An understanding of cultivar responses at tuber formation and during tuber growth is essential to ensure efficient irrigation scheduling. Analysis of yield and its components demonstrated that in general, genotypes are very sensitive to moisture stress at both tuber initiation and tuber-sizing growth stages. The greatest variability among genotypes in response to stress occurred at tuber sizing.

Shepody, Russet Burbank, and Sable showed a strong sensitivity to stress in the tuber initiation phase, whereas Jemseg, Acadia Russet, and Kennebec were more sensitive at tuber sizing.

POTATO PEST MANAGEMENT

Cross-protection with PSTV strains in tomato plants. Analysis by return polyacrylamide gel electrophoresis (R-PAGE) of a mild strain of potato spindle tuber viroid (MA-PSTV) and a severe strain (S-PSTV) showed that both strains replicated in the plant at a similar rate and could be distinguished from each other by different electrophoretic mobilities. In singly infected plants, both strains were detected 10 days after inoculation; in doubly infected plants they were detected 8 days after inoculation. MA-PSTV was detected in all the leaflets of tomato plants 14 days postinoculation, a duration often used before challenge inoculation. In MA-PSTV-protected plants, the challenge strain (S-PSTV) was first detected 21 days after inoculation, and its concentration increased with time. Symptoms of S-PSTV appeared 48 days after challenge inoculation. In unprotected plants, S-PSTV was detected 10 days, and the symptoms appeared 21–28 days, after inoculation. In the top leaves of the MA-PSTV-protected plants, S-PSTV totally replaced the protecting strain in the later stages of infection. Both strains multiplied in the middle and bottom leaves of MA-PSTV-protected plants. In S-PSTV-protected plants, MA-PSTV as a challenge strain was detected only in the later stages of infection but was present in top, middle, and bottom leaves of doubly infected plants. Both strains were found to be present in sepals, petals, anthers, and pistils in MA-PSTV-protected and S-PSTV-challenged plants. Fruit pulp in MA-PSTV-protected and S-PSTV-challenged plants contained only S-PSTV, but fruit pulp in S-PSTV-protected and MA-PSTV-challenged plants contained both strains. Only low percentages of seeds were infected with MA-PSTV, and none were infected with S-PSTV.

Native structural conformations of viroids affect their differential migration on the gel. Citrus exocortis viroid (CEV), tomato apical stunt viroid (TASV), and three strains of potato spindle tuber viroid (PSTV), varying in nucleotide chain length, migrated at various rates when subjected to return polyacrylamide gel electrophoresis (R-Page). Differences of one or two nucleotides in length among three PSTV strains resulted in three separate bands on the gel. Conformational heterogeneity resulting from extraction and purification steps was not responsible for differential migration. The migration pattern was not explained by varying the gel concentrations, the pH of the gel, or the elution profiles of the various strains from CF-11 columns with or without magnesium. Differential migration of various PSTV strains, TASV, and CEV, was also achieved in R-PAGE at various running temperatures (60, 65, 71, and 75°C). Migration rates of mild PSTV strain (MF-PSTV) (358 nucleotides) were slower than the severe PSTV strain (S-PSTV) (360 nucleotides) on non-denaturing gels. Migration was reversed on the denaturing gel. TASV migrated faster than S-PSTV, although both were of 360 nucleotide length. CEV (375 nucleotides) migrated at the same rate as S-PSTV. The data suggest that the conformations in the native structure of viroids are implicated in differential migration on the gel.

The potato mosaic, virus Y, and latent virus S cycle. Areas of New Brunswick seed potatoes rejected for excess mosaic, largely resulting from potato virus Y (PVY), have fluctuated quite regularly, with periodic peaks at an average of 9.4 years between 1922 and 1988. This period differs from the 32-year cycle recently reported for the potato leaf roll virus (PLRV) and runs out of phase with the well-known 11-year sunspot cycle. But during this time it was approximately in phase with a population cycle in Canadian wildlife, known as the Canada hare–lynx cycle.

The difference between the two potato virus cycles is derived from the different modes of transmission of the respective viruses. The prolonged acquisition–transmission sequence of the persistent-type PLRV is accomplished largely by the potato colonizing aphid, *Myzus persicae*, which does not overwinter readily in New Brunswick. By contrast, the non-persistent PVY can be transmitted by a number of aphids that do not necessarily colonize potatoes but visit briefly in search of feeding sites. Many of these aphids are well adapted to the northern climate and lay their eggs on some of the same shrubs and trees that support the hare population. Moreover, the Canada hare–lynx cycle is also reputed to be a northern phenomenon. The transmission of the

mosaic viruses by "native" aphids accounts for the spread of these viruses several weeks earlier in the season than is typical for PLRV and for the fact that years of major spread of the two types of virus frequently do not coincide.

The potato mosaic cycle is actually more complex. During the peak years of the most recent cycle intense spread of the viruses occurred during alternate years (1974, 1976, 1978, 1980, 1982)—in effect, a biennial rhythm. After a double low, or transition, phase (1983, 1984) a new cycle has begun with highs in odd years (1985, 1987). Thus, there has been relatively intense spread of PVY in only 7 of the past 16 years, with no 2 years in succession. The years of relief have had a significant bearing on the status of New Brunswick as a seed-growing area.

During years of relatively intense spread, infections started in late June or early July and accumulated through most of this month while the rapidly growing plants were most susceptible. By 1 August, mature plant resistance was evident. Although spread of virus Y from plant to plant continued, fewer of the infections that occurred after this date resulted in infected tubers. In years of relatively low virus spread, infections commenced later, in mid July, with only a brief period of the susceptible stage of plant growth left.

In an extension of these studies, the spread of the "latent" potato virus S (PVS) in the field was found to start regularly at about the same date as that of PVY, and that PVS has been subject to the same biennial rhythm. This indicates the presence of a strain of PVS that is spread by aphids—virtually the same ones that are prominent in the epidemiology of PVY.

Control of the Colorado potato beetle. The devastating potential of the Colorado potato beetle and the discovery of insecticide-resistant populations often cause growers to apply insecticides in a preventive way. A 3-year field study was carried out to determine the optimal timing of insecticide applications. The stage of the host plant most sensitive to the insect and the abundance of the pest determine that period. On Russet Burbank potatoes in New Brunswick, insecticides applied in mid July at the peak of larval abundance, when plants were entering into bloom, had the greatest efficacy in controlling the beetles and protecting the yield. A single application at 50% bloom was 12–17% and 82–95% more effective than one application at bloom and full growth, respectively.

Timing the spread of PVY. Extensive field testing over a 5-year period showed that PVY spread in New Brunswick starts in mid to late July, when plants reach maximum height. Some 62 different genera or species of aphids were collected in experimental plots. Only seven of these were known vector species. Of the colonizing species, the alate green peach aphid seems to be the most important vector. However, because it is not always present when disease spread starts, noncolonizing aphids are probably responsible for the early spread of PVY. These data indicate that mineral oil sprays, an effective strategy against PVY, need not be applied until mid July. This represents important costs savings and could help reduce the danger of soil compaction by the equipment used to apply the oil.

Isolation and characterization of phytotoxic substances associated with Streptomyces scabies, the causal organism of common scab of potatoes. Earlier attempts at this institution to elucidate the host–parasite interaction of common scab of potato caused by *Streptomyces scabies* (Thaxt.) Waksman & Henrici demonstrated that phytotoxic substances produced extracellularly by pathogenic strains would induce the development of scab-like lesions on immature potato tubers. Through the utilization of modern chromatographic and spectroscopic techniques, the two major phytotoxic substances have now been isolated (from both field-grown and aseptically cultured potato tubers) and characterized as unique 4-nitroindol-3-yl containing 2,5-dioxopiperazines. The toxin identifications, which were also corroborated by detailed synthetic procedures, are seen as a potential milestone in approaches to the eventual understanding of the mechanisms associated with scab disease development. This includes pathogenic specificity, disease susceptibility, and more effective means of control.

ANIMALS AND CROPS

Silage additives give inconsistent results. There was more variation among three replications of the same treatment than among six silage additives tested on second growth alfalfa. The replications were ensiled on 3 consecutive fine days in late July. Although weather conditions were similar each day (cool with bright sun) the first replicate generally produced poor silage, whereas the other two

were excellent. There is no apparent reason for the poor results in replicate 1 except that the weather preceding the day of cutting was warm, with 16 mm of rain. For each replicate the forage was cut the day before ensiling and wilted overnight. Only small differences were noted among treatments or replicates in rate of drop of pH over the first 14 days after ensiling, but in replicate 1 the pH increased between day 14 and day 84.

The digestibility of the silage crude protein was not different for the various treatments as determined with sheep. There were small differences in the digestibility of dry matter. The values for the untreated control silages and those treated with an enzyme or an inoculant were higher ($P > 0.05$) than for the silages treated with an inoculant plus either barley-malt or an enzyme. The silage that had a 9:1 mixture of ground barley and malted barley added at 1% of the weight of forage going into the silo had values that were not different from either the high or low group for dry-matter digestibility.

There were no significant differences in weight gain of beef calves fed four of the silages in a 98-day trial, although those fed the control silage tended ($P > 0.10$) to have the highest gain. They also consumed the most dry matter and were the most efficient at converting feed to weight gain, but the only statistically significant difference was for the silage treated with the inoculant plus barley-malt for dry-matter consumption.

The other two silages were fed to Holstein heifers. Those fed the barley-malt-treated silage had significantly higher ($P < 0.01$) dry-matter intakes and rates of gain ($P < 0.10$) than those fed the enzyme-treated silage. However, these differences were largely due to the fact that enzyme-treated silage from replicate 1 was fed for a longer period than for the replicate 1 barley-malt-treated silage. There was little difference in the daily gain of the heifers when silage from the other two replicates was fed.

The silage additives tested included an inoculant, a cellulolytic enzyme, a source of starch plus amylase enzyme, or combinations of the inoculant with the cellulolytic enzyme or the starch plus amylase. None of these resulted in a significant improvement in replicate 1, where the ensiling conditions were apparently unsatisfactory, or in replicates 2 and 3, where conditions were good.

Near infrared reflectance analysis of farm-grown forage. The suitability of near infrared reflectance (NIR) spectroscopy for determining crude protein, acid detergent fiber (ADF), and neutral detergent fiber (NDF) contents of farm-grown forages depends on the type of forage and whether it is conserved as hay or silage. Although NIR technology offers the advantages in speed, nondestructiveness, and reduced chemical requirements, the accuracy of the predicted values must be acceptable to nutritionists. Six hundred farm-grown forages from Prince Edward Island were sorted into three forage types: grass, legume, or mixed; and two conservation systems: hay or silage. The standard errors crude protein (1% dry matter) ranged from 0.54 for grass hay to 1.12 for grass silage for forages used as validation samples. For ADF (percentage of dry matter) the standard errors ranged from 1.26 for grass hay to 2.31 for mixed silage; for NDF they were from 2.3 for grass silage and grass hay to 3.1 for legume hay. Generally, the constituents of grass hay were predicted with the least error. With legume hays the prediction errors were greater than found with either grass or mixed hays, which was probably because of unrecognized, variable amounts of grasses and broad-leaved weeds contaminating legume stands on farms. The crude protein and ADF contents of silages tended to be estimated with less accuracy than the forages conserved as hay. When all forages were combined within silage or hay groups to provide general prediction equations, the errors about predicted values for grasses increased, whereas those for legumes and mixed forage species were reduced.

As the magnitude of errors about predicted values for ADF and NDF in farm-grown forages was substantial, caution is advisable when incorporating NIR technology into a farm forage testing service.

Drying desiccant-treated large round bales of alfalfa. A commercial desiccant was applied to second- and third-cut alfalfa to decrease its drying time in the field and in an experimental large round bale hay dryer. Desiccant application was found to have a positive effect on the drying time of both cuts of alfalfa.

The drying time was measured from the time the alfalfa was cut to the time it reached 18% moisture. Desiccant-treated hay baled at approximately 35% moisture dried significantly faster than did untreated hay baled at

the same time, regardless of moisture content (87 versus 112 h for treated and untreated second-cut alfalfa, respectively, and 131 versus 166 h for treated and untreated third-cut alfalfa, respectively). However, untreated alfalfa baled at well below 35% moisture dried significantly faster than did the desiccant-treated alfalfa (65 and 104 h for second- and third-cut alfalfa, respectively).

During both trials, reducing the initial moisture content of the bales entering the experimental dryer decreased the drying time. Lower moisture bales were also found to dry more uniformly.

ENGINEERING, HORTICULTURE, SOILS

Harvesting potatoes with steep-angle beds. An experimental harvesting unit was able to dig potatoes and elevate them up a 60° incline. A weighted belt held the tubers on the bed and assisted soil separation. High speeds of the digger bed and weighted belt speeds reduced the average depth of material being elevated and assisted sieving and elevating without affecting the potato damage levels. As expected, tuber temperature and rock concentrations were variables that affected damage levels. The damage index averaged 148 for this unit compared with a commercial harvester level that averaged 297. The best feature of the machine was simplicity.

Effect of strawberry fruit ripeness on shelf-life. The shelf-life of the strawberry cultivars Veestar and Glooscap was prolonged by harvesting at the three-quarters or one-half red stage rather than the full red stage. Full red fruit deteriorated beyond acceptable levels within 3 days when held at 2°C, whereas three-quarters and one-half red berries were still in acceptable condition after 3 days in storage and up to 2 days at room temperature. Fruit harvested at the one-quarter red stage exhibited reduced size and flavor.

The Veestar cultivar stored better than Glooscap, indicating that cultivar selection is an important consideration in extending the shelf-life of strawberries.

Half-high blueberry clones evaluated. Half-high blueberry clones MIN 84, MIN (NB-1), and MIN 354 produced good fruit yields and show promise as a new fruit crop for the region. Lesser yields were produced by other clones—MIN 327, MIN 350, Northblue, and Northsky. Harvests for 1987 and 1988 constitute the first yield results from clones selected from Minnesota highbush × lowbush crosses and planted at Fredericton in 1985 at 4905 plants per hectare. Average yield in 1988 was 1300 g per plant over the seven clones tested. The largest fruit was 135 g per 100 berries by clones MIN 354, MIN (NB-1), and MIN 84, whereas the smallest fruit was produced by Northblue at 44 g per 100 berries.

Nitrate nitrogen in systematic tile drainage waters from potato fields in New Brunswick. Approximately 20 000 ha of potatoes are produced annually in the Upper Saint John River Valley of New Brunswick. Recommended fertilizer N levels range from 120 to 150 kg/ha, and annual yields average 27 t/ha. Several recent studies and reviews have emphasized the potential negative effects of agricultural chemicals on water quality and have indicated that intensive production of shallow-rooted crops such as potatoes are, under high rainfall or irrigated conditions, especially vulnerable to considerable leaching losses of applied fertilizer N.

Flow volumes and NO_3-N contents of drain discharge from five systematically tiled commercial potato fields were measured from April to December 1987 and 1988, to assess the potential for NO_3-N leaching losses associated with current production practices. Three of the five sites were representative of intense potato rotations, and the remaining two were representative of land conversions into potato production from more passive, low-input production systems.

From the 10 site-years of data collected, the flow-weighted average annual nitrate concentration of the drainage effluent, $(NO_3\text{-}N)_f$, was observed to be 10 mg/L or greater for potato site-years, regardless of antecedent crop rotation. $(NO_3\text{-}N)_f$ values of the established potato rotation sites also remained greater than 10 mg/L for the first nonpotato year.

Estimates of residual soil N to 0.6 m depth, determined in November of 1987 and 1988, reflected the increasing or decreasing $(NO_3\text{-}N)_f$ values at each site. Because the drainage systems were operative during winter and spring thaws, when measurements were not recorded, it was not possible to calculate the total annual NO_3-N losses in the drainage water. Total annual NO_3-N losses for the monitored April to December periods ranged from 5 to 33 kg/ha for the potato site-years.

Future research under conditions of controlled land use will help identify more precise interactions among crop rotations, cultural practices, and shallow groundwater quality.

Automation of sunshine duration measurement. The duration of bright sunshine provides some estimate of the availability of radiation for photosynthesis and is a parameter monitored routinely across Canada at all Agriculture Canada weather stations. At present, the parameter is monitored with a Campbell–Stokes sunshine recorder, which consists of a ground-glass ball that focuses the sun's rays onto a time-graduated chart. The sunshine duration is then measured from the chart on which a trace was burnt when the sun was shining. In addition to the daily changing of the recorder chart, abstracting sunshine duration from the chart is not only tedious work but its accuracy is also subject to human error.

To achieve the goal of fully automating the weather station, a prototype differential thermocouple consisting of two copper–constantan junctions, one black and one white, was developed and tested. Polyolefin heat-shrinkable tubings with black and white colors were found to be suitable for the purpose. After 7 months of intensive testing, a threshold value of 0.72°C was determined to be adequate for discriminating between bright sunshine and cloudiness during both winter and summer. Using this value, the automated results are in agreement with those from the Campbell–Stokes recorder, with a correlation coefficient of 0.9. Also, the maximum resolution of the automated sensor is 1 min, which is considerably better than that of the manual recorder.

Applicability of universal soil loss equation. The universal soil loss equation (USLE) is an empirical model designed to predict soil loss by runoff from a specific field under specified cropping and management systems. In the model, soil loss is expressed as a numerical product of combination factors such as rainfall, soil, slope, crop, and support practices. Numerical values for each of these factors are derived from experimental data or computed according to standard methods for areas where experimental data are not available.

Three years of erosion study at Grand Falls reveals that rainfall erosion indexes (R) explain 66–82% of the variation in soil losses from plots at 8 and 11% slopes under various cropping practices. Soil erodibility factor (K) inferred from soil losses is 0.11 for Holmesville soil, whereas values ranging from 0.2 to 0.3 have been used commonly for the same soil in conservation planning. The slope length and slope steepness factors (LS) are very comparable, in which the calculated ratio between the 11 and the 8% slopes is 1.60, whereas the average value based on the experimental data is 1.61. On the other hand, the crop cover and management factors (C) for continuous potatoes planted up and down the 11 and 8% slopes calculated from the experimental data are approximately four times greater than the suggested values. The suggested values are generally inferred from other row crops. The considerably higher C values for potatoes compared with other row crops may be attributed to the physical configuration of potato rows that consist of hills of approximately 60 cm in width and 20–30 cm in height, with slopes of greater than 100%. In addition, the depressional areas between rows that are available for runoff are less than one-third of the total land area. This discrepancy suggests that more locally derived C values are an essential for the use of USLE. The support practice factor (P) accounts for any reduction in soil loss resulting from support practices such as contouring or strip cropping. Comparing the soil losses from contour planting of potatoes with those of planting potatoes up and down the slope, a P value of 0.05 was found. The low P indicates that contour planting of potatoes provides excellent protection against soil erosion.

Dinoseb in subsurface drainage water. The herbicide dinoseb was detected in effluent from systematically tile drained fields in northwest New Brunswick in a cooperative study with Environment Canada and the New Brunswick Department of Agriculture. In samples of subsurface drainage water taken in the spring from three fields, dinoseb applied the previous year was present in concentrations that ranged from 0.11 to 1.1 µg/L. The elapsed time from application to sample collection was 7 months for two fields and 11 months for the other. In another field, dinoseb was present in tile drain effluent in the spring, 23 months after application. Dinoseb could not be detected, however, in a field where it was applied 42 months before sampling. These results suggest that dinoseb will persist in New Brunswick soils for 24–42 months after application.

Dinoseb was detected soon after application to these soils. For example, dinoseb was

applied as a preemergent herbicide on 8 June 1987 at one site. In the first rainfall after application (17 June), dinoseb was not present in the drainage waters. Dinoseb was detected (0.06 – 0.57 µg/L), however, in five sequential samples taken on 28 and 29 June.

In another field, dinoseb was used as a top-killer on 4 September 1987. On 14 September, the concentration of dinoseb in the tile-drain effluent was 44 µg/L. Dinoseb concentrations decreased during the interval between 14 September and 6 October, and in samples taken on 6 October the concentration ranged from 0.17 to 2.00 µg/L. These results suggest that dinoseb is highly mobile in New Brunswick soils.

Although dinoseb is mobile in New Brunswick soils, it is important to keep in perspective the concentrations measured in the subsurface drainage water relative to the application rate. For example, the maximum concentration of dinoseb measured at two sites was multiplied by the total drain outflow. Based on this most-negative situation, between 0.03 and 0.3% of the dinoseb application could be accounted for in the drainage waters.

Concentrations of nitrate N in rural well water. Concentrations of nitrate-N varied from 0 to 31 mg/L in samples of 53 wells taken from 1973 to 1976 and in August and November of 1988. The wells were located in three agricultural areas of New Brunswick, Centreville, Holmesville, and Saint-André, as well as in a nonagricultural area near Fredericton. Mean NO_3-N concentrations and ranges within areas were as follows: Fredericton 1.1 mg/L (0.2–3.4 mg/L); Centreville 5.7 mg/L (0.9–13.7 mg/L); Holmesville 5.0 mg/L (1.7–9.9 mg/L); and Saint-André 9.5 mg/L (4.0–31 mg/L). Thirteen percent of the wells in the Centreville area and 39% of those in the Saint-André area had NO_3 concentrations that exceeded the Health and Welfare Canada limit of 10 mg/L for drinking water. No wells in the other two areas had NO_3 concentrations that exceeded the 10 mg/L limit.

The mean concentration of NO_3 in well water decreased in the Centreville area over the course of the study. The average concentration of NO_3 from 1973 to 1976 was 6.3 mg/L and 3.7 mg/L in 1988. No change in mean NO_3-N concentrations occurred in the Holmesville and Saint-André areas. Fredericton wells were not sampled from 1973 to 1976.

The Department of Health and Welfare guidelines of 10 coliform organisms per 100 mL were exceeded in 33% of the wells in the Centreville area, 36% of those in the Holmesville area, and 22% of those in Saint-André. No coliform bacteria were present in wells in the Fredericton area.

There was no apparent association between the presence of coliform organisms and NO_3 concentrations; when wells containing more than 10 coliform organisms per 100 mL were excluded from analysis, mean NO_3 concentrations within areas were unaltered. Evidently, the presence of NO_3 in the well waters of the three agricultural areas was not due to leakage from septic fields or to infiltration of surface waters. It is speculated that the elevated NO_3 concentrations may be due to leaching, into the ground water, of N-containing fertilizers or soil N.

Draft–depth relationships in a pedogenetically compacted clay loam soil. An experiment was carried out to determine force–depth relationships under constant speed for a subsoiler using a tine with three different wing types operating in a pedogenetically compacted clay loam soil. The results revealed that the vertical force on the tine increased linearly with operating depth. The horizontal force, moment, and total force increased quadratically with operating depth. Wing width had a significant effect on the vertical force, whereas no interaction existed between depth and wing width. Wing width had only interactive effects on the horizontal force, moment, and total force. The vertical force was small relative to the horizontal force; therefore the horizontal force dominated the moment and total force on the tine under the conditions tested. The angle of application of the total force on the tine varied with depth and with wing width. The data were compared with a three-dimensional soil wedge model of soil failure that accurately predicted the total force but underestimated the horizontal force and greatly overestimated the vertical force.

Reconsolidation of Salisbury silt loam. Neither limestone ($CaCO_3$) nor gypsum ($CaSO_4$), added at 0.5 and 0.08% w/w, respectively, had an effect on the optimum moisture content and maximum dry bulk density of the standard Proctor test. The addition of peat (2.0%, w/w) lowered the maximum dry bulk density from 1.84 mg/m^3 to 1.73 mg/m^3 and

increased the optimum moisture content to 16.8% (w/w) from 14.8% (w/w). These results are contrary to those obtained from the low-energy compaction test, designed to simulate a 0.44 m soil overburden, in which the chemical amendments increased the dry bulk density and the volumetric moisture content at a soil moisture tension of 101 kPa. This finding may reflect a susceptibility of soils treated with $CaCO_3$ and $CaSO_4$ for reconsolidation after deep ripping. The standard Proctor test did not reveal this. Soil strength, as measured by the cone index from penetrometer studies, was decreased by the addition of $CaCO_3$ or $CaSO_4$; however, when corrected for volumetric moisture content, no treatment effect on soil strength was observed.

Spectral analysis of the forces on a subsoiler. Autocorrelations were determined for lags up to 400 on horizontal and vertical forces recorded digitally at 100 Hz over 30-s periods. Smoothed spectral density estimators, calculated using Parzen lag windows of 100, 200, and 400, revealed that the major portion of the power developed in both the horizontal and vertical forces was at frequencies of less than 1 Hz and was attributed to variation in soil parameters. A significant peak consistently appeared between 3 and 10 Hz. The frequency, band width, and power contribution to a filtered spectrum were then regressed against depth of operation and wing type. For both the horizontal and vertical forces, the frequency associated with the peak and the band width of that peak were decreased by the addition of wings and further decreased by increasing the width of those wings. Depth of operation had no effect on these parameters. The power contribution to the filtered spectrum associated with these peaks was found to increase with depth for both the horizontal and vertical forces. It is suggested that this frequency is related to the development of shear planes within the soil caused by the action of the subsoiler blade.

Senator Hervé J. Michaud Experimental Farm, Bouctouche, N.B.

Raspberry late yellow rust. Late yellow rust *Pucciniastrum americanum* (Farl.) Arth. was a problem in red raspberry (*Rubus idaeus* L.) plantings of the Atlantic Provinces of Canada. A program to determine the optimum schedule of fungicide applications for rust control based on the life cycle of the pathogen was established. Anilazine (Dyrene) applications at the time of alciospore release from the alternative host, white spruce *Picea glauca* (Moench) Voss., reduced leaf and fruit infections. A program of three anilazine applications early in the season, terminating before flowering, gave the best disease control.

Carottes. L'utilisation de billons pour la production de carottes sur une tourbière au Nouveau-Brunswick a donné de bons résultats au cours des deux dernières années. Les rendements commercialisables de carottes ont été plus élevés (environ 10 %) avec les billons qu'avec les semis classiques sur le plat. Les carottes étaient légèrement plus longues sur les billons; on comptait aussi plus de carottes du calibre 32–45 mm (63 % contre 51 %). On attribue ces résultats favorables à un drainage amélioré et à un meilleur réchauffement du sol avec les billons.

Choux de bruxelles. L'évaluation de plusieurs cultivars de 1980 à 1986 démontre que le cultivar Predora a constamment produit un excellent rendement sans incidence marquée de brunissement interne. Son seul désavantage a été sa maturité tardive. Les cultivars Jade Cross et Jade Cross E ont également obtenu d'excellents rendements tout en affichant un faible taux de brunissement interne. Ces deux cultivars sont d'une maturité hâtive. Les cultivars Prince Marvel, Silverstar et Widgeon semblent sensibles au brunissement interne. Conséquemment, ils ne se prêteraient pas au marché de congélation qui exige un faible pourcentage de brunissement interne. Bien que le cultivar Valiant se soit classé septième pour le rendement, il affichait le pourcentage le plus élevé de choux de petit calibre. Il avait également une faible incidence de brunissement interne.

Luzerne. Deux essais régionaux de cultivars de luzerne ont été semés à Bouctouche, un en 1986 (12 cultivars) et l'autre en 1987 (14 cultivars). L'essai semé en 1986 s'est mieux établi que celui semé en 1987. Les résultats de la récolte de 1987 sur l'essai semé en 1986 ont montré des rendements de 5,1 t/ha à 4,3 t/ha M.S. Le cultivar O.A.C. Minto s'est classé au premier rang, suivi du Saranac et de l'Apica.

Research Station, Fredericton, N.B.

En 1988, des rendements de 13,8 t/ha à 11,7 t/ha M.S. ont été obtenus pour l'essai semé en 1986, et de 11,2 t/ha à 9,0 t/ha M.S. pour l'essai semé en 1987. Le cultivar O.A.C. Minto s'est à nouveau classé au premier rang, suivi de NRG-83-01 Syn 2 et DK135 (semis 1986). Dans l'essai semé en 1987, le Vertibenda était au premier rang, suivi du Saranac et de l'Iroquois.

Maïs ensilage. Les résultats de 3 années d'évaluation de cultivars de maïs ensilage ont montré les possibilités de cette culture sous nos conditions climatiques. Pour les hybrides hâtifs, le K730 avait un rendement moyen de 9,3 t/ha M.S. sur 2 ans (1987–1988), le G-4083 8,2 t/ha M.S. sur 3 ans (1986, 1987, 1988) et le Pumas 7,3 t/ha M.S. sur 3 ans (1986, 1987, 1988). En ce qui concerne les hybrides tardifs, le Coop S259 avait un rendement de 11,5 t/ha M.S. sur 3 ans (1986, 1987, 1988), le Bishop 30–30 11,0 t/ha M.S. sur 3 ans (1986, 1987, 1988) et le 3957 (Pioneer) 10,9 t/ha M.S. sur 3 ans (1986, 1987, 1988).

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INTRODUCTION

La mission du Centre de recherches alimentaires de Saint-Hyacinthe est d'aider l'industrie des aliments et des boissons du Canada afin de leur permettre de devenir plus efficaces et productifs et par conséquent plus compétitifs.

Le Centre favorise la recherche sur le lait, les viandes, les nouveaux ingrédients et la conservation des produits frais. Les disciplines représentées au Centre sont la chimie, la microbiologie, la chimie-physique, la biochimie, la physiologie végétale, la bio-ingénierie, le génie alimentaire.

Le Centre possède un éventail d'instruments modernes qui permettront de mener des expériences complexes dans le but de réaliser des progrès rapides en recherche. Au Centre, on privilégie les réalisations avec l'industrie; celle-ci peut profiter d'une usine pilote dont les instruments permettent de mettre au point de nouveaux produits à base de céréales, de lait et de viandes. De plus, nous possédons des ressources financières qui permettent d'aider l'industrie dans la réalisation de projets de recherche.

Ce rapport résume quelques-unes des principales réalisations du Centre en 1988 dont on trouvera la description détaillée dans les articles scientifiques cités dans la bibliographie.

Le Centre de recherches alimentaires de Saint-Hyacinthe a accueilli en 1988 le Service de recherches sur les aliments (SRA) du Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec. Une entente concernant l'utilisation conjointe du Centre a été signée par le ministre d'État à l'Agriculture, Pierre Blais, par le ministre de l'Agriculture, des Pêcheries et de l'Alimentation, Michel Pagé, et par le ministre délégué aux Affaires intergouvernementales canadiennes pour le Québec, Gil Rémillard.

Le Centre fédéral de recherches alimentaires et le Service provincial de recherches sur les aliments travaillent de concert à l'harmonisation et l'orientation des programmes de recherche. L'équipe de B. Aurouze, chef du SRA, est composée d'une vingtaine de personnes dont six chercheurs.

Pour de plus amples renseignements, s'adresser au Centre de recherches alimentaires de Saint-Hyacinthe, 3600, boul. Casavant ouest, Saint-Hyacinthe, Québec, J2S 8E3; tél. (514) 773-1105.

Claude B. Aubé
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PHYSIOLOGIE VÉGÉTALE ET ATMOSPHÈRE CONTRÔLÉE

Conservation du brocoli et du chou-fleur sous atmosphère contrôlée. La conservation du brocoli peut être prolongée par une atmosphère modifiée contenant 2,5 % d'O_2 et de 6 à 8 % de CO_2. Une atmosphère contenant peu d'O_2 (2,5 %) a réduit la respiration, la production d'éthylène, l'activité de l'enzyme formant l'éthylène (EFE) et le contenu en ACC, le précurseur immédiat de l'éthylène, et retarde le climactérique et la sénescence. Le contrôle de la synthèse de l'éthylène semble se faire au niveau de l'EFE, et non au niveau de l'ACC synthétase. Le froid (1 °C) réduit considérablement la sensibilité des bourgeons du brocoli à l'éthylène. Il réduit également la synthèse de l'éthylène, en réduisant l'activité de l'EFE. Un traitement à l'éthylène accélère le climactérique en stimulant l'EFE, sans effet notable sur l'ACC synthétase.

La sénescence du brocoli montre une bonne corrélation avec la dégradation des phospholipides et l'augmentation du rapport stérol/phospholipide. Ces changements dans la composition des lipides membranaires sont ralentis par une atmosphère modifiée contenant 2,5 % d'O_2 et 8,5 % de CO_2 qui retarde la sénescence.

Les choux-fleurs se conservent mieux sous une atmosphère contenant 3 % d'O_2 et 5 % de CO_2. Une atmosphère de 3 % d'O_2, ainsi qu'un prétraitement pendant 24 h à 15 % de CO_2 causent le jaunissement et le ramollissement des tissus. L'acide succinique s'accumule quand la concentration de CO_2 est élevée.

Irradiation des produits végétaux (En collaboration avec l'Université Laval). L'irradiation des produits végétaux cause souvent le ramollissement des tissus. L'étude de l'effet de l'irradiation des fraises à 4 kGy sur les parois cellulaires a démontré que les parois étaient partiellement dégradées. La cellulose et les chaînes d'acide polygalacturonique des fractions pectiques et de l'hémicellulose ont été affectées. Les chaînes de sucres neutres sont relativement résistantes aux rayons ionisants.

Pour éviter le risque de ramollissement et diminuer les effets indésirables de l'irradiation des fraises, il est possible de combiner une dose très légère (0,25 kGy) d'irradiation avec une atmosphère modifiée contenant 10 % de CO_2 et 5 % d'O_2. Les deux méthodes ont des effets synergiques.

L'irradiation des fraises à 2,0 kGy entraîne une légère dégradation des phospholipides. Les acides gras de ces phospholipides ne sont pas affectés. Une dose de 4,0 kGy cause une forte augmentation de la conductivité électrique des tissus, ce qui indique des dommages importants aux membranes cellulaires.

La méthode de détection et de mesure de l'irradiation dans la viande, décrite récemment par des scientifiques du National Bureau of Standards (NBS) des États-Unis. et qui est basée sur la présence d'*o*-tyrosine dans les protéines, n'est applicable qu'aux fraises. En effet, l'*o*-tyrosine a été détectée en petite quantité aussi bien dans les protéines des fraises irradiées que dans des échantillons témoins.

PRODUCTION DES ENZYMES LACTOBACILLES

L'étude vise à utiliser les enzymes microbiens, en particulier les enzymes de lactobacilles, dans la fabrication du fromage et la maturation du fromage cheddar. Nous avons étudié 20 souches d'espèces *Lactobacillus casei* du point de vue de leurs activités enzymatiques.

Les peptidases et esterases de trois *Lactobacillus casei* ont été produits, purifiés et caractérisés sur les systèmes de FPLC et PHAST. L'étude a porté sur quatre peptidases (amino, di, tri, carboxy) et trois esterases (butyrate, caproate, capryate). Nos résultats ont démontré que la fabrication d'arômes de fromages est facilement réalisable pendant 1 à 2 jours, et aussi que le fait d'ajouter des enzymes augmente d'une façon significative l'indice de maturation du cheddar.

GÉNIE GÉNÉTIQUE

Nous faisons appel aux techniques du génie génétique pour augmenter le potentiel industriel de certains microorganismes. Le gène de la lactase de *Streptococcus thermophilus* a été introduit dans la levure *Saccharomyces cerevisiae*. Une cartographie à l'aide d'enzymes de restriction de l'ADN donné indique que le gène se retrouve sur un fragment de 3,4 kb. Ceci nous a permis de détecter l'activité 3-galactosidasique dans la levure transformée. De plus, le produit de l'expression du gène cloné dans la levure est thermostable comme pour la bactérie d'origine. Nous séquençons ce gène et étudions le mécanisme de sécrétion de la lactase dans *S. cerevisiae*. La production d'une levure capable de croître sur lactosérum est un grand apport pour l'industrie laitière.

Nous avons caractérisé les plasmides de *Lactobacillus casei* et avons mis au point une technique de clonage de gènes d'estérase (Capryate) de *Lactobacillus casei* dans *Streptococcus lactis*.

PRODUCTION DE BIOMASSE DE *Leuconostoc oenos*

En oenologie, des cultures de *Leuconostoc oenos* peuvent être ajoutées au jus de raisin ou au vin afin d'y favoriser la fermentation malolactique. La conversion de l'acide malique en acide lactique et CO par cette bactérie permet de réduire l'acidité des vins et d'en accroître la stabilité. Nous avons déterminé les conditions permettant de produire des biomasses (pour être ultérieurement séchées et utilisées pour inoculer les moûts) de *L. oenos* dans le jus de pomme. Des milieux ayant diverses teneurs en solides de jus de pomme ont été supplémentés en peptones et extraits de levure. La croissance de *L. oenos* dans les jus de pomme sans suppléments n'était pas élevée et les rendements n'étaient pas influencés par la teneur en solides. Les extraits de levures se sont avérés les meilleurs pour stimuler la croissance de *L. oenos*. Les peptones issus d'hydrolysats de caséine de viande ou de soja ont été préférés aux mycopeptones. La préférence pour les milieux stérilisés par chauffage ou filtration variait selon la souche. Les zones optimales de pH et de température pour la croissance étaient de 4,5 à 4,8 et de 28 à 32° respectivement. Lorsque la fermentation

ne s'effectuait pas en contrôle pH, la plupart des souches acidifiaient le milieu. La production de biomasse en contrôle de pH (4,7) a permis d'accroître les rendements de 60 %. Dans ces conditions, *L. oeni* utilisait presque tout l'acide malique disponible, mais nous avons observé d'importantes quantités de sucres résiduels. Parmi divers autres suppléments ajoutés (jus de tomate, vitamines, nucléotides, Mn ou acide malique), seul l'acide malique a permis une reprise de fermentation.

INHIBITION DES BACTÉRIES PSYCHROTROPHES

Des laits crus ont été inoculés avec des cultures lactiques spécifiquement destinés à inhiber la croissance des bactéries psychrotrophes. Des additions de moins de 3 millions de bactéries lactiques (BL) par millilitre n'ont pas inhibé de façon significative la croissance des psychrotrophes du lait cru réfrigéré (7 °C), les BL ont acidifié le lait jusqu'à un pH de 6,6 lors des ensemencements de 25 millions par millilitre. L'inhibition des psychrotrophes n'était toutefois pas reliée à cette acidification. Nous n'avons pas observé de corrélations élevées entre l'efficacité de l'inhibition et la population initiale des bactéries psychrotrophes dans le lait ou son taux de croissance. De façon globale, toutefois, l'addition de BL inhibe davantage les flores psychrotrophes qui démontrent un pouvoir de développement rapide dans le lait. Les bactéries psychrotrophes se développent mieux dans les laits stérilisés que dans les crus. Nous avons démontré qu'il est également possible d'inhiber la croissance des psychrotrophes par l'addition de bactéries lactiques immobilisées dans un gel d'alginate. Les psychrotrophes se développent mieux dans les laits agités, mais l'efficacité de l'inhibition de BL immobilisées y est aussi supérieure. L'emploi de BL immobilisées à cette fin permet de retirer la plupart des bactéries inoculées. Ainsi nous n'avons retrouvé que 30 000 BL/mL dans le lait cru.

DÉVELOPPEMENT DE CONTAMINANTS DANS DES SYSTÈMES À CELLULES IMMOBILISÉES

Lorsque les cellules sont immobilisées dans des gels d'alginate, il est possible de les récupérer suite à la fermentation. Les mêmes cellules peuvent donc servir pour plusieurs fermentations consécutives. Ceci soulève la possibilité de contaminations lors de l'utilisation industrielle des systèmes à cellules immobilisées (CE). Nous avons donc volontairement contaminé un système à bactéries lactiques immobilisées avec des bactériophages ou des levures et avons observé leur développement au cours de cinq fermentations consécutives en employant les mêmes CE. Les bactériophages se sont développés rapidement dans un milieu et ont atteint des populations de plus de 1 milliard par millilitre de lait. Les bactéries situées à l'intérieur de la matrice d'alginate n'étaient pas affectées. Ainsi malgré une population importante de phages, le système CE démontre un taux d'acidification presque identique au témoin sans phages. Les phages infectaient les cellules libres du milieu. Le nombre de cellules libres a donc diminué au cours des trois premières fermentations. Nous avons toutefois observé l'apparition d'une population résistante au cours des deux dernières fermentations. Un rinçage du système n'a pas empêché l'implantation du phage. La contamination par les levures pouvait être pour sa part contrôlée. Les levures ne sont pas implantées dans les systèmes et un rinçage a accéléré leur élimination.

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C. Farmer, B.Sc.(Agr.), M.Sc., Ph.D.	Régie—porcs
J.G. Lussier,[4] B.Sc.(Biochim.), D.M.V., M.Sc.	Santé et reproduction animales
G. Pelletier, B.Sc.(Agr.), M.Sc., Ph.D.	Physiologie de la digestion—bovins
S.A. Pommier, B.Sc., M.Sc., Ph.D.	Qualité des viandes—bovins, porcs
S. Robert,[5] D.M.V., Ph.D.	Éthologie et physiologie

Production laitière

L.A. Guilbault, B.Sc., M.Sc., D.E.A. (Nutr.), Ph.D.	Chef de section; physiologie de la reproduction—bovins
C.L. Girard, B.Sc.(Agr.), M.Sc., Ph.D.	Nutrition—jeunes ruminants
F. Grasso, B.Sc.(Agr.), M.Sc. physiologie	Assistant; recherche de la reproduction—bovins
B. Lachance, B.Sc.(Agr.), M.Sc.	Nutrition—jeunes ruminants
H. Lapierre, B.A., M.Sc., Ph.D.	Physiologie et nutrition
D. Petitclerc, B.Sc., B.Sc.(Agr.), M.Sc., Ph.D.	Physiologie de la lactation—bovins
G.L. Roy, B.S.A., M.Sc., Ph.D.	Génétique—bovins
C.M. Vinet, B.Sc.(Bio.), M.Sc., Ph.D.	Nutrition—bovins laitiers

Exploitation des plantes fourragères

P.M. Flipot, B.Sc.(Agr.), M.Sc., Ph.D.	Chef de section; nutrition—bovins de boucherie
G.M. Barnett, B.Sc.(Agr.), M.Sc.	Régie et environnement
J. Chiquette, B.Sc.(Agr.), M.Sc., Ph.D.	Microbiologie du rumen
C. Fernet, B.Sc.	Amélioration des plantes
A.R. Pesant, B.Sc.(Agr.), M.Sc.	Physique des sols
H.V. Petit, B.Sc.(Agr.), M.Sc., Ph.D.	Physiologie de la digestion—bovins
P. Savoie, B.Sc.(Agr.), M.Sc., Ph.D.	Génie des plantes fourragères

Départ

J.L. Dionne, B.A., B.Sc.(Agr.), Ph.D. Retraite, janvier 1988	Fertilité des sols

CHERCHEURS INVITÉS

Étudiants à la maîtrise

A. Abbar responsable, P. Savoie	Génie rural
D. Baril responsable, A.R. Pesant	Géographie
S. Beauregard responsable, P. Savoie	Génie rural
P. Dumoulin responsable, C.L. Girard	Nutrition—jeunes ruminants
D. Jannini responsable, P.M. Flipot	Nutrition—bovins de boucherie
P. Lacasse responsable, D. Petitclerc	Physiologie de la lactation
S. Lapierre responsable, L.A. Guilbault	Physiologie de la reproduction
J. Lareau responsable, A.R. Pesant	Physique des sols
M. Letendre responsable, J.J. Matte	Nutrition—porcs
A. Marcoux responsable, P. Savoie	Génie rural
P. Rouiller responsable, L.A. Guilbault	Physiologie de la reproduction
N. Roy responsable, G. Pelletier	Physiologie de la croissance et de la digestion
F. Salehi responsable, A.R. Pesant	Physique des sols
H. Su responsable, G.L. Roy	Génétique—bovins laitiers
D. Tremblay responsable, P. Savoie	Génie rural
J. Vigneux responsable, A.R. Pesant	Physique des sols

Étudiants au doctorat

S. Manga responsable, P. Savoie	Géographie
C. Pomar responsable, P. Savoie	Analyse de systèmes
P. Villeneuve responsable, L.A. Guilbault	Physiologie de la reproduction

S.P. Wang — Génétique—bovins laitiers
responsable, G.L. Roy

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[1] M. J.G. Proulx agit à titre de Directeur intérimaire à compter du 3 janvier 1989.
[2] Détachée de la Direction générale de la gestion intégrée, Division des bibliothèques.
[3] En congé d'études post-doctorales, Wageningen Agricultural University, The Netherlands.
[4] En congé d'études de doctorat, Université de la Saskatchewan.
[5] Poste déterminé.

INTRODUCTION

La Station de recherches de Lennoxville a été fondée en 1914. Une douzaine de chercheurs y travaillaient jusqu'au début des années 1970. En 1980, on a commencé à embaucher les étudiant(e)s à la maîtrise ou au doctorat pour appuyer les programmes de recherches. La Station étant située près de Sherbrooke, nos chercheurs entretiennent une fructueuse collaboration avec ceux du Département de biologie de l'Université de Sherbrooke. Les chercheur(e)s de la Station participent aussi activement à des projets de recherches avec la Faculté de médecine et la Faculté de médecine vétérinaire de l'Université de Montréal, la Faculté des sciences de l'agriculture et de l'alimentation de l'Université Laval, formant ainsi un groupe de travail qui étudie différents aspects de la production bovine et porcine. Vingt-quatre projets conjoints sont actuellement en cours avec l'industrie, 22 avec les universités, 10 avec des institutions provinciales et huit avec d'autres institutions fédérales.

Les activités de recherches de la Station de Lennoxville sont principalement axées sur la zootechnie. La majeure partie des ressources de la Station sont assignées aux programmes en productions laitière et porcine. Dans la section des bovins laitiers et celle des animaux d'abattage, des équipes multidisciplinaires, comportant des spécialistes en génétique, nutrition, physiologie, comportement et régie, travaillent à améliorer la productivité et la rentabilité de ces élevages dans l'est du Canada. Une troisième section regroupe les chercheurs dont les études sont axées sur l'exploitation des plantes fourragères. Les recherches visent à mettre au point des méthodes améliorées de récolte et de conservation des fourrages et à augmenter l'utilisation des plantes fourragères dans la diète des ruminants et plus spécifiquement des bovins de boucherie; d'autres études sur la régie des fumiers, la fertilité et l'érosion ont pour objectifs d'augmenter la productivité des sols et d'en freiner la dégradation.

Le budget opérationnel de la Station de recherches de Lennoxville est de 1,3 millions de dollars. L'effectif de la Station est de 94 années-personnes, dont 24 chercheurs. Pour soutenir la recherche, la Station de recherches possède une ferme d'environ 400 ha.

On peut obtenir des renseignements plus complets en écrivant directement aux chercheurs à l'adresse suivante: Station de recherches, Direction générale de la recherche, Agriculture Canada, C.P. 90, 2000, route 108 Est, Lennoxville, Québec, J1M 1Z3; tél. (819) 565-9171.

J.G. Proulx
Directeur intérimaire

ANIMAUX D'ABATTAGE

Effets du type de plancher sur la teneur en folates et en vitamine B_{12} ainsi que sur les performances zootechniques du porc d'abattage. Quarante-huit porcelets, âgés de 5 semaines, ont été utilisés afin de déterminer l'effet du type de plancher sur l'évolution des concentrations sériques de folates et de vitamine B_{12}, ainsi que sur les performances zootechniques du porc d'abattage. Pendant 18 semaines, ces animaux ont été élevés soit sur un plancher de type plein (libre accès aux fèces) soit sur un plancher à caillebotis (accès limité aux fèces). À tous les 14 jours, chaque animal a été pesé et un échantillon sanguin a été prélevé afin de déterminer les concentrations sériques en folates et en vitamine B_{12}. Le type de plancher n'a pas eu d'effet ($P > 0,05$) sur les concentrations sériques de folates et de vitamine B_{12}, lesquelles étaient respectivement de 72,2 ± 2,9 ng/mL et 246,0 ± 21,3 pg/mL, à la fin de l'expérience. Entre l'âge de 5 et 11 semaines, le taux de croissance des porcs gardés sur plancher à caillebotis a été supérieur ($P \leq 0,05$) à celui des porcs gardés sur plancher plein. De 11 à 23 semaines, cependant, le taux de croissance a été le même ($P \geq 0,05$) sur les deux types de plancher. Les résultats semblent indiquer que, dans les conditions de cette expérience, la coprophagie n'est pas un moyen efficace de combler les besoins en vitamines du complexe B chez le porc en croissance.

Influence de la castration et d'un traitement à la testostérone sur la sécrétion d'hormone de croissance chez le porc. Chez la plupart des mammifères, les mâles atteignent à l'âge adulte une taille plus grande que les femelles. Ce phénomène pourrait être dû à l'action

indirecte des hormones sexuelles sur d'autres facteurs de croissance, telle l'hormone de croissance GH. Chez le porc, on a démontré que les concentrations sériques de GH sont plus faibles chez les castrats que chez les femelles; la réponse de cette hormone après stimulation à la somatocrinine est également plus grande chez les femelles. On a fait une expérience dans le but de déterminer l'effet de la castration et d'un traitement à la testostérone d'une durée de 10 jours consécutifs sur la sécrétion basale et stimulée à la somatocrinine de la GH chez le porc d'engraissement. Les résultats obtenus indiquent que les mâles castrés avaient une concentration sanguine de GH plus basse que les animaux témoins non castrés. Dans les deux groupes la concentration diminue avec l'âge pour les deux traitements. Cependant, l'administration de proprionate de testostérone n'a pas permis d'augmenter les concentrations sanguines de GH même si les niveaux sanguins de testostérone ont été augmentés. Par ailleurs, la stimulation à la somatocrinine a doublé les concentrations de GH; cette réponse a aussi été influencée par l'âge et la castration, mais non par le traitement à la testostérone.

Effet de traitements avec des facteurs hypothalamiques sur le comportement des truies pendant la lactation et sur leur réponse à la régie du sevrage. L'effet d'une administration quotidienne de somatocrinine (GRF) et/ou de thyréolibérine (TRF) sur le comportement durant la lactation et au sevrage a été étudié chez 51 truies primipares. Durant la lactation, les truies recevant du TRF, seul ou en combinaison avec du GRF, passaient un plus grand pourcentage de temps couchées sur le côté que les truies recevant de la saline ou seulement du GRF. Cette différence pourrait être causée par une stimulation du comportement maternel. Au jour du sevrage, on n'a observé aucun effet de traitement sur le comportement des truies laissées dans leurs cages de mise bas. Cependant, dans un autre groupe de truies ayant été déplacées, les sujets traités au GRF seulement ou au TRF seulement étaient plus agités, plus souvent couchés sur le ventre et moins souvent sur le côté que les truies recevant de la saline ou le traitement combiné GRF–TRF. Ces résultats suggèrent que les traitements avec des facteurs hypothalamiques n'ont pas d'effets néfastes sur le bien-être des truies mais qu'ils modifient leurs réponses au stress.

PRODUCTION LAITIÈRE

Influence de la présence d'un embryon sur la fonction ovarienne. On a déterminé chez la génisse laitière l'influence en début de gestation de la présence d'un embryon sur le retour en chaleur et la fonction lutéale suite à une lutéolyse provoquée avec des prostaglandines. Les résultats indiquent que l'intervalle entre l'injection de prostaglandines et le retour en chaleur ne varie pas en fonction de la présence d'un embryon ($P > 0,1$). Cependant, la fonction lutéale du cycle oestral suivant l'injection de prostaglandines est réduite en présence d'un embryon ($P < 0,01$) lorsque la lutéolyse est provoquée chez une génisse en gestation depuis 24 jours. Des signaux d'origine embryonnaire influencent donc la fonction ovarienne en tout début de gestation. Ces résultats suggèrent également que le problème associé aux cycles oestraux ou phases lutéales de courte durée chez les vaches en début de période post-partum peut être engendré dès le 24e jour de gestation.

Développement des follicules ovariens chez la vache. Le développement des follicules ovariens a été étudié chez la vache durant le cycle oestral. L'index mitotique (IM) a été évalué pour les follicules de différents diamètres provenant d'ovaires non traités (T0) et traités 2 h (T2) à la colchicine. L'IM à T0 est peu élevé pour les follicules de petit diamètre (de 0,13 à 0,28 mm), augmente en relation avec le diamètre folliculaire entre 0,68 et 1,52 mm, puis diminue pour les follicules dont le diamètre est supérieur à 3,67 mm. La durée moyenne de la mitose (TM) d'une cellule de la granulosa a été estimée à 0,99 ± 0,14 h; cependant la TM varie selon les classes folliculaires, soit 1,32 h pour les follicules de petit diamètre (0,13–0,67 mm) et 0,78 h pour les follicules de 0,68 mm ou plus. À partir du temps requis par un follicule pour doubler son nombre de cellules de granulosa, on a évalué qu'un follicule nécessite environ 41,5 jours pour accroître son diamètre de 0,13 à 8,56 mm. Cette période représentant le stade antral du développement folliculaire s'étend donc sur environ deux cycles oestraux. On a également observé une corrélation positive entre le nombre de follicules et leur temps de passage à travers les différentes classes folliculaires. Les résultats suggèrent que la croissance des

follicules de 0,68 à 1,58 mm constitue une étape critique dans le développement folliculaire chez la vache si l'on se base sur l'augmentation de la proportion des follicules en dégénérescence ainsi que sur leur taux de croissance élevé.

Effet d'un supplément d'acide folique sur la croissance des génisses. Quarante-sept génisses de type laitier, âgées d'environ 10 jours, ont été assignées à une expérience de type factoriel où l'apport en acide folique (0 ou 40 mg) et le niveau de consommation alimentaire ont été les deux facteurs étudiés. Les animaux, sevrés 4 semaines après l'entrée à l'étable, ont reçu un foin de graminées et des concentrés à deux niveaux différents: à volonté ou de façon à restreindre le gain de poids quotidien à 700 g. Pendant les 16 semaines d'expérience, les génisses ont reçu une injection intramusculaire hebdomadaire de saline ou de 40 mg d'acide folique. De la 5e à la 16e semaine d'expérience, le gain de poids des animaux nourris à volonté a été supérieur à celui des animaux dont l'alimentation était restreinte. De la 5e à la 9e semaine d'élevage, le supplément d'acide folique a amélioré le gain de poids des génisses. De plus, cet avantage s'est maintenu jusqu'à la fin de l'expérience. Ces résultats indiquent qu'un supplément d'acide folique administré pendant la période d'établissement et de stabilisation de la fonction ruminale améliore le gain de poids des génisses laitières.

Remplacement du maïs par l'orge dans l'alimentation des vaches en lactation. Une étude a été entreprise afin d'évaluer l'impact du remplacement du maïs par l'orge dans la diète sur les performances zootechniques de la vache en lactation. Dès le vêlage, 47 vaches ont reçu au hasard l'une de deux rations totales mélangées dont la céréale principale était du maïs concassé ou de l'orge roulée. Entre la 3e et la 26e semaine de lactation, l'utilisation de l'orge ou du maïs dans la ration totale mélangée n'a pas influencé ($P > 0,05$) la production de lait (30,9 contre 30,3 kg/jour), la composition en gras (3,86 contre 3,78 %) ou en protéines (3,26 contre 3,26 %) du lait, la consommation de matière sèche (22,3 contre 22,0 kg/jour), l'efficacité alimentaire brute (1,38 contre 1,38 kg de lait par kilogramme de matière sèche consommée) ou le poids moyen (668 contre 661 kg). On a satisfait les besoins des vaches en protéines et en énergie dès la 4e semaine de la lactation. L'alimentation de la vache laitière avec une ration totale mélangée dont la principale céréale est l'orge roulée n'influence donc pas négativement les performances zootechniques entre la 3e et la 26e semaine de lactation.

Infusion de glucose dans le duodénum de veaux recevant un lactoremplaceur non coagulable. Quatre veaux mâles Holstein, âgés de 7 à 10 jours et munis d'une canule duodénale, ont reçu un lactoremplaceur non coagulable formulé à partir de poudre de lait écrémé séchée à basse température. Une solution tampon oxalate–NaOH a été ajoutée afin d'empêcher la coagulation du lactoremplaceur. On a réparti ces veaux au hasard en deux groupes et ils ont reçu une infusion duodénale de solution saline (témoin), ou de solution saline contenant du glucose (traitement). L'expérience a été répétée de façon à ce que chaque veau reçoive les deux types d'infusion. L'infusion de glucose a amélioré la rétention azotée et a diminué les concentrations plasmatiques d'acides aminés et d'urée. Les concentrations plasmatiques d'insuline et de triglycérides n'ont pas été influencées par l'infusion de glucose. Un apport supplémentaire d'énergie sous forme de glucose est donc nécessaire afin d'optimiser l'utilisation de l'azote d'origine alimentaire lorsque le veau préruminant reçoit un lactoremplaceur non coagulable.

EXPLOITATION DES PLANTES FOURRAGÈRES

Pertes de sol, d'azote et de phosphore au cours d'une pluie de forte intensité. Deux pluies de forte intensité (63 mm/h) d'une durée de 30 min chacune ont été appliquées à l'aide d'un simulateur de pluie sur des parcelles de loam argileux de 15 m^2. Le laps de temps entre les ondées était d'une demi-heure. À toutes les 5 min, nous avons mesuré les quantités de sol érodé, d'azote et de phosphore entraînées par les eaux de ruissellement au bas d'une pente de 11 %. Le taux de ruissellement a été plus élevé à la seconde pluie qu'à la première puisque l'humidité du sol avait atteint le point de saturation. En effet, au cours de la deuxième ondée, la quantité de sol érodé était de 11,1 kg avec un taux de ruissellement de 83 % alors que, durant la première ondée, la quantité de sol érodé était de 6,4 kg avec un taux de ruissellement inférieur à 54 %. On a observé

des interactions significatives (ondées × périodes) quant aux pertes de sol et aux quantités d'azote et de phosphore dissoutes dans l'eau de ruissellement. Ainsi, durant la première ondée, les pertes ont augmenté linéairement entre la période de 5 min et celle de 30 min alors qu'au cours de la seconde, les pertes ont plutôt augmenté de façon quadratique. Dans l'ensemble, les quantités d'azote et de phosphore perdues ont suivi la même tendance que le ruissellement.

Effet du surconditionnement sur la durée du séchage des fourrages. De récents travaux de recherche ont démontré qu'il était possible d'accélérer le séchage des fourrages au champ de 20 à 60 % à l'aide des techniques de fenaison présentement disponibles sur le marché (faneurs à toupies, retourneurs d'andains, conditionnement chimique). Il est important de faire sécher le foin au champ le plus rapidement possible afin d'éviter le lessivage par la pluie et les pertes de la valeur nutritive du fourrage. Avec les techniques actuelles, 2 à 3 jours de beau temps sont nécessaires pour récolter un foin sec de qualité. Une nouvelle technique de conditionnement mécanique qui broie le fourrage et le presse en une mince natte de 6 mm d'épaisseur accélère le séchage de plus de 300 %. Ce surconditionnement, parfois appelé macération, permettrait de récolter du foin sec en une seule journée. Des essais en laboratoire ont démontré l'effet bénéfique de ce surconditionneur sur la luzerne. D'ici un an, un prototype à l'échelle commerciale devrait nous permettre de vérifier dans des conditions naturelles les résultats obtenus en laboratoire.

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Sainte-Foy, Québec

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INTRODUCTION

La Station de recherches de Sainte-Foy a été fondée en avril 1967. En plus de l'établissement à Sainte-Foy, elle regroupe les fermes de La Pocatière et de Normandin, ainsi que la ferme Jean-Charles Chapais à Saint-David de l'Auberivière. Sa situation près du campus de l'Université Laval et des principaux effectifs du gouvernement provincial favorise les échanges avec le personnel scientifique et de vulgarisation de ces établissements.

Le mandat de la Station porte sur les plantes fourragères, les céréales, les sols et l'eau. Six groupes de chercheurs se partagent les travaux de recherches portant sur les plantes fourragères, les céréales, la physiologie et la biochimie des plantes, les sols, la microbiologie et le soutien à la recherche. Des travaux en horticulture, sur les bovins laitiers et sur les ovins sont aussi effectués aux fermes de La Pocatière et de Normandin.

Les budgets d'opération pour les trois établissements de Sainte-Foy et Saint-David de l'Auberivière, La Pocatière et Normandin respectivement sont de 960 000 $, 340 000 $ et 230 000 $. Les années-personnes sont de 74, 32 et 25 dont 27, 3 et 3 chercheurs. Les terrains accessibles représentent respectivement 75, 240 et 140 ha pour Sainte-Foy, La Pocatière et Normandin.

Ce rapport présente les principaux faits saillants de la recherche effectuée en 1988. Vous pouvez obtenir des renseignements plus complets en vous adressant à la Station de recherches d'Agriculture Canada, sise au 2560, boul. Hochelaga, à Sainte-Foy (Québec), Canada, G1V 2J3; tél. (418) 657-7980.

S.J. Bourget
Directeur

AMÉLIORATION ET GESTION DES SOLS ET DES PLANTES

Amélioration génétique des céréales

Le cultivar d'orge Chapais. Le nouveau cultivar Chapais, un cultivar d'orge à six rangs créé à la Station de Sainte-Foy, est enregistré au Canada depuis 1988. Ce cultivar est caractérisé par de hauts rendements en grains, une paille courte et de force supérieure, de gros grains, une tolérance au virus de la jaunisse nanisante de l'orge et une très bonne résistance à l'acidité du sol. Le cultivar Chapais est bien adapté à toutes les régions de l'est du Canada et démontre une bonne résistance à la pourriture des racines dans l'ouest du pays. De plus, suite à des essais de régie, le cultivar Chapais a démontré une bonne plasticité lorsque comparé à des cultivars utilisés en régie intensive.

Orge à deux rangs. Les caractéristiques recherchées chez un cultivar d'orge à deux rangs pour le Québec est un haut rendement en grains et une adaptation aux conditions de croissance locales. Douze lignées issues d'un croisement impliquant quatre parents sont très prometteuses après deux années d'évaluation au champ; on a noté des rendements plus élevés que les cultivars témoins et une résistance au charbon et au mildiou.

Blé roux de printemps panifiable. En plus des caractéristiques agronomiques, 28 paramètres de qualité doivent être considérés dans un programme d'amélioration génétique du blé panifiable. En 1988, les efforts de sélection pour la qualité panifiable du blé roux de printemps ont porté sur la teneur en protéines et sur la dureté des grains (PSI) chez les premières générations de ségrégation en utilisant la technologie du proche infrarouge. Cette stratégie vise l'élimination de tous les génotypes ne répondant pas aux critères de base afin de n'évaluer au champ que les lignées ayant un potentiel panifiable. Sur les 16 000 lignées produites et sélectionnées, à peine quelques centaines ont répondu aux exigences de base.

Dureté et teneur en protéines des grains de blé. La teneur en protéines et la dureté des grains de blé varient en fonction de leur stade de développement. Au stade de développement 75 de l'échelle de Zadoks (mi-laiteux), le pourcentage de protéines des grains est très élevé, puis diminue à son plus bas niveau au stade 80 (début pâteux) pour ensuite augmenter et demeurer constant à partir du stade 85 (pâteux mou), soit au début de la maturité physiologique. La dureté des grains de blé panifiable augmente graduellement entre les stades 75 (mi-laiteux) et 85 (pâteux

mou) tandis que celle des grains de blé non panifiable ne varie pas durant ces mêmes stades de développement. La sélection des lignées de blé potentiellement panifiables peut donc être effectuée lorsque les grains ont atteint leur maturité physiologique.

Identification de la qualité des blés tendres avec l'infrarouge. En collaboration avec le Département des sciences et technologies des aliments de l'Université Laval, des techniques de regroupement hiérarchique et d'analyse discriminantes multiples appliquées à des spectres dans le proche infrarouge de 125 lignées de blé de qualités différentes ont été utilisées pour distinguer les qualités de panification et les paramètres rhéologiques, biochimiques et physico-chimiques de ces lignées. L'analyse discriminante multiple s'est avérée très efficace pour identifier les lignées de blé en reclassifiant près de 90 % de ceux-ci. Cette étude laisse entrevoir la possibilité d'utiliser l'analyse en groupe hiérarchique sur des populations de blé en ségrégation et de regrouper les différentes lignées selon leur niveau de ressemblance avec les lignées parentales. En raison de sa facilité d'utilisation et des ressources minimales nécessaires, cette technique offre un potentiel énorme pour les programmes de sélection utilisant des parents de qualité différente.

Croisements intergénériques. Les hybrides du blé avec le *Leymus innovatus* et le *Psathyrostachys juncea* ont été rétrocroisés avec le blé. Plusieurs *Leymus* et *Agropyron* ont démontré une quasi immunité au virus de la jaunisse nanisante de l'orge (VJNO) et une résistance au puceron vecteur du *Rhopalosiphum padi*; ces caractéristiques sont héritables de façon additive. La résistance au puceron était introuvable chez le genre *Triticum*. Les hybrides interspécifiques subissent donc actuellement trois types de sélection: virus de la jaunisse nanisante de l'orge, pucerons et, chez le blé d'automne, mortalité hivernale. La résistance au VJNO revêt une importance particulière car elle permet une meilleure croissance racinaire et confère une certaine résistance à la sécheresse.

Nouvelles méthodes d'hybridation. Des méthodes biotechnologiques originales permettent maintenant d'hybrider le blé avec des espèces très lointaines comme le maïs *Zea mays*, le sorgho *Sorghum vulgare* et le mil à chandelle *Pennisetum typhoides*. La plupart des hybrides donnent des blés haploïdes quoiqu'un hybride contenant un chromosome de maïs ait été obtenu. Le transfert de certains caractères du maïs au blé est présentement à l'étude.

Amélioration génétique des légumineuses fourragères

Résistance à la verticilliose chez la luzerne. Depuis l'apparition de la verticilliose au Québec en 1986, un effort marqué a été fait pour le développement de populations de luzerne *Medicago sativa* résistantes à cette maladie. On a inoculé et transplanté au champ plus de 12 000 plants et sélectionné plusieurs centaines de génotypes résistants. On a produit de la semence de génération syn-2 pour quatre populations dont le niveau de résistance varie de modérément résistant à résistant. Ces populations seront introduites en 1989 dans les essais d'enregistrement du Québec et des provinces maritimes.

Sélection pour la résistance multiple. Dans le but d'accroître le rendement et la persistance de la luzerne, on a effectué des croisements, des inoculations artificielles et des sélections afin d'incorporer dans différentes populations expérimentales la résistance à la pourriture phytophthoréenne, au flétrissement bactérien et à la verticilliose. On a produit de la semence de génération syn-1 à partir de quatre cultivars expérimentaux qui combinent la résistance à ces trois maladies.

Amélioration du trèfle rouge. Une importante collection de cultivars européens et nord-américains de trèfle rouge *Trifolium pratense* a été évaluée conjointement à Sainte-Foy et au Collège Macdonald. Les cultivars nord-américains ont démontré une meilleure persistance. Les résultats obtenus ne semblent pas confirmer la supériorité des cultivars de trèfle tétraploïde sur les cultivars de trèfle diploïde, ni des cultivars de trèfle à une coupe sur ceux à deux coupes pour ce qui a trait au rendement fourrager et à la persistance. Quelques cultivars européens semblent intéressants à utiliser dans un programme d'amélioration génétique de cette légumineuse fourragère.

Amélioration génétique des graminées fourragères

Caractéristiques morphologiques et qualité de la fléole des prés. Une étude visant à évaluer la relation entre divers caractères morphologiques et la qualité nutritive de la

fléole des prés, *Phleum pratense*, a permis d'identifier certains paramètres morphologiques qui permettent de sélectionner les génotypes de fléole des prés ayant à la fois un potentiel de rendement élevé et une bonne qualité nutritive. Toutefois, on a noté une corrélation indésirable entre une bonne qualité et un mauvais rendement fourrager ce qui signifie qu'il faut se résoudre à faire un compromis biologique entre une productivité élevée et une bonne qualité nutritive pour cette graminée fourragère.

Amélioration de la qualité nutritive de la fléole des prés. Des populations divergentes de fléole des prés ont été obtenues après un premier cycle de sélection phénotypique pour la teneur en protéines brutes (PB), la digestibilité et le rendement digestible. Évaluées en plants espacés, ces populations ont montré des différences significatives pour la digestibilité, les teneurs en PB et en parois cellulaires. Évaluées en parcelles, on a noté des différences entre les populations pour le ADF, le NDF et la rétention d'eau. Suite à l'évaluation de différents paramètres de production potentielle de lait, il s'est avéré qu'un cycle de sélection de la fléole des prés soit suffisant pour modifier la production animale. Ces derniers résultats devront toutefois être vérifiés avec des animaux.

Évaluation de cultivars d'espèces fourragères

Essais de cultivars de luzerne et de fléole des prés. L'évaluation de cultivars de luzerne et de fléole des prés pour le Québec s'est poursuivie en 1988 avec l'aide des stations coopérantes. Les cultivars de luzerne Armor et Thunder ont été ajoutés à la liste des cultivars recommandés pour le Québec en 1989 tandis que le cultivar de fléole des prés Tiller a été recommandé pour son enregistrement au Canada.

Exploitation des plantes fourragères

Gestion de la luzerne. Les résultats additionnels obtenus en 1988 d'un essai visant à déterminer la période critique de repos automnal de la luzerne sur cinq sites différents ont confirmé les observations antérieures à l'effet que des coupes effectuées durant les premières semaines de septembre sont très néfastes à la survie de la luzerne. Les coupes effectuées à la fin de septembre ou au début d'octobre ont assuré un meilleur rendement fourrager mais de qualité inférieure. Des analyses de qualité sur le fourrage récolté permettront de développer un régime d'exploitation qui va permettre de prendre en considération la productivité, la qualité et la persistance de cette culture.

Physique et conservation des sols

Matière organique du sol. Une méthode d'analyse des glucides du sol a été mise au point. Après hydrolyse dans une solution acide, les teneurs en glucose, galactose, mannose, arabinose et xylose de la matière organique du sol sont déterminées par chromatographie liquide à haute performance (HPLC) en utilisant une colonne HPX-87P de BIO-RAD. Cette méthode simple et rapide permet, entre autres, d'étudier la nature et l'origine des glucides impliqués dans la stabilisation des agrégats du sol.

Stabilité structurale des sols en fonction des cultures exploitées. Après trois saisons de croissance, les cultures d'orge et de luzerne ont augmenté de 50 % la stabilité et la taille des agrégats d'un sol argileux de la série Kamouraska lorsque comparés à l'état initial ou aux parcelles maintenues en jachère. Par contre, le sol sous maïs ne présentait pas une agrégation différente du sol laissé en jachère. L'évaluation de la consolidation des agrégats par la méthode d'oxydation au périodate a confirmé que les polysaccharides des racines des plantes et la fraction humifiée de la matière organique du sol ont contribué à la stabilisation des agrégats.

Fertilisation des sols

Effet des copeaux de bois et des fertilisants azotés sur le rendement de la fléole des prés et de l'orge. Une étude menée au champ durant 3 ans a permis de constater l'effet de deux types de copeaux de bois appliqués à trois doses, de trois sources d'azote—inorganique, fumier et lisier—et de deux profondeurs d'enfouissement sur le rendement de la fléole des prés et de l'orge. Les facteurs à l'étude n'ont pas fait varier significativement les rendements en grains de l'orge. Toutefois, pour la fléole des prés, le lisier a permis d'obtenir systématiquement de meilleurs rendements en fourrage que les deux autres sources d'azote. Les rendements fourragers de la fléole des prés ont diminué significativement, quoique faiblement, avec l'augmentation des doses de copeaux ajoutés. Cependant, lors de la

première année de récolte, les doses croissantes de copeaux ont entraîné une augmentation des rendements fourragers lorsque de l'azote inorganique était utilisé. Le type de copeaux et la profondeur d'enfouissement ont été sans effet sur le rendement de la fléole des prés. L'ajout de copeaux de bois a eu peu d'effet sur la teneur en carbone organique du sol après 3 ans de culture de fléole des prés ou d'orge.

Dynamique du potassium et du magnésium dans les sols du Québec. Une grande partie du territoire agricole du Québec est potentiellement déficiente en potassium (K) et en magnésium (Mg). Les espèces pérennes comme la luzerne dépendent des fractions échangeables et lentement échangeables pour leur alimentation en ces deux éléments nutritifs. Une étude dont l'objectif est de déterminer la dynamique de la libération du K et du Mg à l'aide de solutions d'acide citrique permet d'établir des corrélations hautement significatives entre le taux de libération et la quantité de K non échangeable libérée d'une part, et la teneur initiale en K sous forme échangeable d'autre part. La libération du K était également reliée à la teneur en argile grossière (0,2–2 µm) des sols, mais non à des différences d'ordre minéralogique ou d'origine géologique. Les quantités de Mg libérées étaient statistiquement reliées à la capacité d'échange cationique des sols. Les résultats d'une seconde étude, menée en milieu contrôlé sur la luzerne cultivée dans 30 sols de la province, montrent que la fraction dite non échangeable contribue d'une façon importante à l'alimentation potassique de la luzerne. Cette contribution était d'autant plus importante que la teneur en argile du sol augmentait. L'apport relatif des fractions non échangeables qui ne sont pas habituellement évaluées par l'analyse de sol classique devrait être considéré si nous voulons tendre vers l'utilisation optimale des fertilisants potassiques et ainsi diminuer les risques de pollution des eaux d'écoulement.

Malherbologie

Démographie du chiendent. Avec la collaboration de chercheurs affiliés à d'autres centres de recherches, l'étude de la démographie du chiendent *Agropyron repens* a été poursuivie afin de modéliser le développement des populations de bourgeons de rhizomes. La taille optimale des échantillons qui doivent être prélevés pour évaluer les populations de rhizomes a été définie à huit échantillons de 15 × 15 cm/m² de surface de sol. Cette taille d'échantillonnage constitue un compromis acceptable entre le degré de précision désiré et le coût financier de l'échantillonnage.

Compétition spargoute-luzerne. Une étude a été entreprise au champ afin de déterminer la période critique de compétition entre la spargoute des champs *Spergula arvensis* et la luzerne. Les résultats préliminaires indiquent que la période de compétition se situe entre la troisième et la cinquième semaine après le semis.

PHYTOPROTECTION ET PHYSIOLOGIE

Pathologie des légumineuses fourragères

Bactéries glaçogènes. Ces microorganismes (INA+) qui colonisent naturellement le xylème des racines de la luzerne ont la capacité d'élever considérablement la température de cristallisation de l'eau en surfusion dans les tissus. La température à laquelle l'eau libre dans les racines gèle est d'environ −7 °C pour les racines exemptes de bactéries nucléatrices alors qu'elle se situe aux environs de −3 °C dans les racines colonisées par les bactéries INA+.

Verticilliose de la luzerne. Cette maladie causée par le *Verticillium albo-atrum* affecte la résistance au froid de la luzerne de façon marquée. La tolérance au gel (LT-50) de l'Apica, cultivar sensible à la verticilliose, a été seulement de −3,2 °C pour les plantes malades alors qu'il a été de −9,1 °C pour les plantes saines, une différence de 5,8 °C. Cette différence n'a été que de 1,1 °C après trois cycles de sélection pour augmenter la résistance à cette maladie. La verticilliose affecte également le rendement des cultivars sensibles; ceux-ci ont donné 20 % moins de rendement que les cultivars résistants.

Les symbioses végétales

Souches de Rhizobium arctiques pour le sainfoin. Les souches arctiques de *Rhizobium* isolées des légumineuses des genres *Astragalus* et *Oxytropis* sont adaptées au froid et sont efficaces à fixer l'azote dans le sainfoin *Onobrychis viciifolia*. L'effet toxique des tannins, composés phénoliques exudés des graines de sainfoin, sur la croissance des souches arctiques de *Rhizobium* a été mesuré sur un milieu à

l'extrait de levure et au mannitol; on a observé l'effet inhibiteur des tannins pour toutes les souches. Toutefois, lorsque le milieu de culture contient un supplément de fer, cet effet est renversé. La sensibilité des souches aux tannins n'est pas corrélée à leur efficacité symbiotique avec la plante.

Efficacité des souches arctiques de Rhizobium sur l'astragale pois-chiche. Une étude sur l'efficacité symbiotique de 33 souches arctiques de *Rhizobium* avec l'astragale pois-chiche *Astragalus cicer*, une légumineuse dont le rendement fourrager se rapproche de celui de la luzerne, a montré qu'à la première coupe, aucune des souches arctiques n'a donné des rendements aussi élevés que les souches commerciales utilisées comme témoins. À la deuxième coupe, sept souches arctiques ont été classées moyennement efficaces et deux, aussi efficaces que les souches commerciales. À la troisième coupe, sept souches arctiques ont donné des rendements semblables à ceux obtenus avec les souches commerciales. Contrairement aux souches commerciales dont le rendement à la troisième coupe représentait seulement 50 % du rendement maximum à la première coupe, les souches arctiques efficaces ont assuré à l'astragale pois-chiche un rendement qui se maintenait ou augmentait avec les coupes.

Caractérisation sérologique des souches arctiques de Rhizobium. L'analyse des antigènes internes a permis d'établir les relations taxonomiques des 48 souches arctiques entre elles et avec sept autres espèces connues des genres *Rhizobium* et *Bradyrhizobium*. Les analyses d'immunodiffusion contre les anticorps de quatre souches arctiques ont permis de montrer que les souches arctiques sont fortement apparentées entre elles et avec les souches appartenant à d'autres espèces d'*Astragalus* et d'*Oxytropis*. Le *Rhizobium leguminosarum* partage quelques antigènes avec les souches arctiques et on a observé de faibles réactions avec le *R. meliloti* et le *R. loti*. Les souches arctiques n'ont pas d'antigène commun avec le *Bradyrhizobium japonicum*. Ces résultats appuient les conclusions tirées des autres propriétés analysées qui classaient les souches arctiques du *Rhizobium* dans un groupe distinct.

Contribution des légumineuses arctiques au bilan azoté. Une analyse détaillée des données recueillies sur le terrain concernant l'activité de fixation d'azote de *Oxytropis maydelliana*, *O. arctobia* et *Astragalus alpinus*, trois légumineuses arctiques, indique que ces plantes apportent une contribution majeure au bilan azoté de la toundra arctique. L'activité nitrogénasique (N_2-ase) des plantes intactes est en corrélation avec le nombre de nodules par plant, avec les températures du sol et avec la disponibilité de l'eau. La N_2-ase des nodules détachés montre une activité maximale entre 10 et 20 °C, et un déclin linéaire avec la température jusqu'à −5 °C. Les nodules sont plus nombreux dans la zone plus chaude du sol (de 2 à 10 cm) et ils sont pérennes. La croissance des nodules et leur production de leghémoglobine recommencent à chaque printemps à partir du méristème apical qui a hiverné.

Induction et expression de la nitrogénase des Rhizobium arctiques. Une étude en milieu contrôlé sur l'expression *ex planta* de la nitrogénase (N_2-ase) dans une souche de *Rhizobium* arctique a indiqué que les polysaccharides extracellulaires (EPS) diminuent la diffusion de l'oxygène vers les cellules bactériennes à un niveau qui permet l'induction de la N_2-ase, et par la suite la fixation d'azote. Une étroite zone de concentration en EPS favorisant un équilibre de la tension d'oxygène autour des cellules est la condition requise pour obtenir l'induction et l'expression de cette enzyme dans la bactérie en culture liquide.

Rhizosphère du maïs. L'identification morphologique et biochimique des rhizobactéries de la rhizosphère du maïs a démontré que cette rhizosphère est dominée par les bactéries du genre *Pseudomonas*, suivi par des *Bacillus* et des *Serratia* en nombre beaucoup plus restreint. À l'intérieur de la racine, la population microbienne est en grande partie composée de *Bacillus*, suivi de quelques *Pseudomonas*. Les tests en serre ont permis l'isolation de deux souches bactériennes, la *Serratia liquefasciens* et la *Pseudomonas* sp., qui ont contribué à augmenter le rendement du maïs de façon constante sur deux types de sol. Des tests au champ sont présentement en cours, de même que des expériences visant à déterminer le mécanisme d'action de ces bactéries sur les plants de maïs.

Endomycorhize-Rhizobium chez la luzerne. Une étude en milieu contrôlé a permis de constater un effet synergétique très significatif de la double symbiose chez la luzerne. Suite à ces résultats, on a entrepris une expérience au

champ qui permettra de déterminer le degré de persistance du synergisme, l'influence de la double symbiose sur la reprise de la croissance des plants au printemps, la résistance aux maladies et au froid, la teneur en protéines brutes et le contenu minéral des plants, ainsi que la rentabilité de cette double symbiose.

Endomycorhize-poireau. Une étude a permis de vérifier l'impact de doses élevées de phosphore (P) sur la croissance des plants de poireau *Allium porrum* endomycorhizés et non mycorhizés. À tous les niveaux de P appliqués, la croissance des plants endomycorhizés a été supérieure aux plants témoins. De plus, contrairement à ce qui est rapporté dans les publications, la colonisation endomycorhizienne est demeurée constante quel que soit le niveau de P appliqué. La technique de précolonisation des plantules mise au point à Sainte-Foy doit donc favoriser le développement du champignon endomycorhizien à l'intérieur de la racine et dans la rhizosphère. Par contre, l'inoculation *in situ* des plantules avec des segments de racines colonisées ne réussit que lorsque la concentration en P dans le sol est relativement faible.

Mécanismes de résistance au froid des plantes

Régulation des niveaux de polyamines. L'exposition de plantes à des stress entraîne une augmentation de la teneur en putrescine. Une étude a été menée en retenant la putrescine comme marqueur biologique afin de vérifier si l'exposition de plantes à un premier stress pouvait modifier leur réponse à un stress ultérieur de nature différente; on a retenu comme deuxième stress l'utilisation des basses températures comme premier stress et la déshydratation—un stress osmotique—ou l'incubation dans l'acide abscissique (ABA). Les collets des plants des cultivars de blé Kharkov et Champlain ont présenté un comportement identique à la suite de l'exposition au mannitol, un agent de déshydratation, à l'ABA ou à une combinaison ABA-mannitol, que les plants aient été ou non préalablement endurcis au froid. Au cours de l'exposition à un deuxième stress, on a observé peu de variations de la teneur en putrescine, spermidine et spermine. Le contenu en putrescine était de 4 à 6 fois supérieur dans le matériel préalablement exposé aux basses températures par rapport au matériel témoin. À l'opposé de la situation constatée dans les collets, le stress osmotique ainsi que la combinaison ABA-mannitol ont entraîné dans le matériel témoin une augmentation importante de la putrescine dans les feuilles, une augmentation de 75 nmol/g de produit frais au début du traitement jusqu'à 2 300 nmol/g de produit frais après 48 h d'exposition à un deuxième stress. Dans les feuilles, la spermidine a augmenté de quatre fois durant cette période et la spermine est demeurée stable. D'autre part, les feuilles provenant de plants de blé endurcis aux basses températures n'ont pas présenté une augmentation de putrescine comparable à celle observée avec le matériel témoin; suite au trempage racinaire dans le mannitol ou le mélange ABA-mannitol, la putrescine n'a que doublé dans le matériel endurci au froid alors que l'exposition à l'acide abscissique n'a pas modifié la teneur en polyamines.

Dosage des sucres solubles et de l'amidon. L'évolution de la teneur en sucres solubles et en amidon au cours d'une période d'endurcissement au froid a été étudiée avec divers cultivars de luzerne, de blé, de seigle *Secale cereale*, d'avoine et de fléole des prés; la mesure de l'amidon a été déterminée par colorimétrie tandis que l'analyse des sucres solubles a été effectuée par chromatographie liquide à haute performance (HPLC). Les résultats indiquent que les températures froides ont affecté le niveau des sucres solubles de façon marquée. On a observé des différences importantes entre la luzerne d'une part et les céréales et les graminées fourragères d'autre part. En effet, chez la luzerne, le sucrose a été le sucre soluble le plus abondant et s'est accumulé de façon importante alors que les niveaux de fructose et de glucose sont demeurés stables. Chez les autres espèces étudiées, le sucrose était un composé mineur qui variait peu au cours du traitement. Par contre, le glucose et le fructose s'accumulaient au cours de l'exposition au froid. Chez toutes les espèces étudiées, l'amidon présentait une baisse d'abondance au début de la période d'exposition au froid pour augmenter progressivement par la suite. Bien que les sucres solubles et l'amidon se soient accumulés chez toutes les espèces durant une exposition au froid, il n'est pas certain que les niveaux de ces constituants puissent être utilisés comme indicateurs d'endurcissement au froid ou comme marqueurs de rusticité.

Test sur la tolérance au gel

Évaluation de la rusticité de plantules de luzerne. Sous des conditions contrôlées, la luzerne est habituellement testée pour la tolérance au gel lorsque les plants ont entre 28 et 35 jours de croissance. Toutefois, une étude montre que dès le sixième jour après la germination, la tolérance au gel peut être détectée chez les jeunes plantules de luzerne. La séparation des cultivars pour la sélection est possible vers le 20e jour. À cet âge, les plantules sont suffisamment petites pour permettre une manutention beaucoup plus aisée tout en permettant une économie d'espace lors de l'endurcissement et des tests de congélation.

FERME EXPÉRIMENTALE DE LA POCATIÈRE

Les plantes fourragères

Compétition luzerne-pissenlit. Dans un essai effectué en serre, nous avons introduit des plants de pissenlit *Taraxacum officinale* Weber dans un peuplement de luzerne. Après 260 jours, la présence du pissenlit n'a pas affecté la biomasse aérienne de la luzerne. Toutefois, la biomasse racinaire de la luzerne a été réduite lorsque le peuplement de pissenlit a atteint 12 plants par pot. La biomasse aérienne ainsi que la biomasse racinaire du pissenlit ont diminué proportionnellement avec le peuplement de la luzerne. En l'absence de mortalité, la souplesse d'adaptation à la compétition du pissenlit permet d'expliquer sa survie dans un peuplement de luzerne établi.

Essais de cultivars de dactyle. L'évaluation de cultivars de dactyle, *Dactylis glomerata* L., pour le Québec, s'est poursuivie en 1988 avec l'aide des stations coopérantes. Le cultivar OR-WH a fait l'objet d'une demande d'enregistrement et sera ultérieurement ajouté à la liste des cultivars recommandés de dactyle pour le Québec.

Luzerne vivace non dormante. Les espèces fourragères annuelles adaptées aux conditions climatiques du Québec qui permettraient de réchapper une production fourragère affectée par des dommages hivernaux sérieux sont rarissimes. Nous avons donc comparé la performance des cultivars de luzerne Apica et de trèfle rouge Tristan avec celle du cultivar de luzerne Nitro, une luzerne vivace non dormante qui se comporte comme une espèce annuelle dans les régions tempérées. Les trois cultivars ont été ensemencés au champ sur un sol argileux de la série Kamouraska et sur un sol loam graveleux de la série Saint-André. Les résultats préliminaires montrent que le cultivar de luzerne Nitro n'a pas surpassé en rendement les deux autres cultivars sur les deux types de sol; le cultivar de trèfle rouge Tristan a donné la meilleure production de fourrage suivi du cultivar de luzerne Apica et du cultivar de luzerne Nitro.

Horticulture

Amélioration de la pomme de terre. L'amélioration génétique de la pomme de terre s'est poursuivie en 1988 et 177 croisements ont été réussis avec différentes lignées et cultivars afin d'augmenter le rendement, les qualités culinaires et de transformation, principalement pour les croustilles. Le programme a alimenté le réseau provincial d'évaluation avec 20 nouvelles lignées. Plusieurs de ces lignées ont également fait l'objet d'évaluation dans les quatre programmes canadiens d'amélioration. Les lignées LP8058 et LP8120 produites à La Pocatière sont prometteuses. La lignée LP8058 qui a été présentée à l'enregistrement intérimaire est mi-hâtive, a un haut rendement et est utilisable principalement pour le marché frais. La lignée LP8120 a une chair jaune, est de calibre moyen, a une maturité mi-saison et est très bonne pour la cuisson à l'eau, de bonne à moyenne pour les croustilles et se reconditionne assez bien; cette lignée sera présentée à l'enregistrement intérimaire en 1989.

Pathologie de la pomme de terre. Une nouvelle méthode d'échantillonnage de tiges a été développée et évaluée pour dépister le flétrissement bactérien de la pomme de terre au champ. Les résultats obtenus avec le tubercule de semence et avec le tubercule de la pomme de terre de consommation sont très concluants, car il y a eu jusqu'à 7 échantillons positifs sur 10 dans un champ servant à la consommation alors qu'un seul échantillon de semence s'est avéré positif. Cette méthode permet d'obtenir les résultats des tests de laboratoire avant le défanage de la culture ce qui laisse plusieurs alternatives à l'inspecteur et au producteur lorsque les tests sont positifs.

Défanage de la pomme de terre. Les résultats d'une étude de 3 années menée au champ montrent que l'herbicide glufosinate est moins efficace que le diquat comme défanant de

la pomme de terre. Les feuilles et les tiges traitées avec le glufosinate ont desséché plus lentement. De plus, le glufosinate était plus sensible au délavage par la pluie. Finalement, les applications simples ou divisées et l'emploi d'un pulvérisateur classique ou à gouttelettes contrôlées n'ont pas amélioré l'efficacité du glufosinate.

Cultures fruitières et ornementales

Arbres fruitiers. Il y avait respectivement 179, 131 et 126 pruniers en évaluation en 1986, 1987 et 1988 et ils ont produit en tout 3 100, 1 890 et 1 530 kg de fruits par année. Les cultivars Stanley, Bradshaw-Blue, Lévis, Mont-Royal, l'Islet et Veeblue ont été les plus productifs avec 48, 44, 29, 25, 23 et 23 kg de fruits par arbre en moyenne. Les vieux poiriers ont donné de bons rendements; les cultivars Miney et Phileson ont produit respectivement 325 et 350 kg de fruits par arbre.

FERME EXPÉRIMENTALE DE NORMANDIN

Les plantes fourragères

Essais comparatifs de graminées fourragères. Une étude de productivité des quatre principales graminées fourragères utilisées dans la région démontrent que l'alpiste roseau *Phalaris arundinacea* L. a rendu le plus de matière sèche, suivi de la fléole des prés, du brome *Bromus inermis* Leyss et du dactyle. Chez le brome, le cultivar Tempo a un rendement supérieur au cultivar Baylor tandis que le cultivar d'alpiste roseau Vantage a été plus productif que le cultivar Frontier; les rendements des cultivars de fléole des prés Basho et Champ ainsi que des cultivars de dactyle Frode et Pennlate n'ont pas différé chez une même espèce. La plus haute teneur en protéines brutes a été enregistrée avec le dactyle tandis que le fourrage de la fléole des prés possédait la plus faible teneur en protéines brutes. De plus, le dactyle a produit le fourrage le plus digestible tandis que la digestibilité du fourrage de l'alpiste roseau était la plus faible.

Seuil de nuisibilité du chiendent dans la luzerne. Les résultats d'une étude effectuée pendant 2 années consécutives démontrent que sans plante-abri, le chiendent a réduit la croissance de la luzerne. À chaque année, suivant l'établissement, les peuplements de luzerne ont été supérieurs dans les parcelles désherbées. En semis pur, le chiendent a augmenté le rendement fourrager total, mais a réduit la qualité du fourrage durant l'année du semis. La qualité du fourrage telle qu'estimée par le contenu en parois cellulaires a été réduite à des densités de chiendent dépassant 300 tiges par mètre carré; des densités supérieures étaient nécessaires pour qu'il y ait réduction du taux de protéines brutes. Le seuil de nuisibilité du chiendent dans une luzernière se situe donc entre 150 et 300 tiges par mètre carré; à des densités supérieures, le chiendent réduit significativement la qualité du fourrage récolté.

Maïs fourrager. Selon les résultats d'un essai effectué à Lac-à-la-Croix au Lac-Saint-Jean, le pourcentage de matière sèche à la récolte des plants entiers d'hybrides de maïs fourrager COOP 120 (2 600 UTM), Pioneer 3 992 et 3 994 (respectivement 2 300 et 2 250 UTM) et Funk's 4 077 (2 200 UTM) était inférieur à 22 % tandis que celui des épis de ces hybrides était de 26 %; la contribution moyenne de l'épi au rendement total n'a pas dépassé 30 %. La forte teneur en humidité des plants entiers et des épis à la récolte expliquent, en partie, la faible popularité de cette culture dans la région.

Sorgho fourrager. Un essai mené au champ pendant 3 années a permis de constater que les conditions climatiques particulièrement fraîches de la région du Saguenay-Lac-Saint-Jean ne permettent pas d'obtenir des rendements fourragers élevés avec le sorgho. Toutefois, récolté lorsque les plants avaient atteint un mètre de hauteur, le sorgho fournit un fourrage de qualité avec une teneur en protéines brutes supérieure à 19 % et une digestibilité (ADF) d'environ 28 %.

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[6] Affecté au programme de recherche de l'ACDI sur les sols arides au Pakistan.

INTRODUCTION

La Station de recherches de Saint-Jean-sur-Richelieu a été implantée en 1940 pour répondre aux problèmes de protection des pomiculteurs. Le mandat s'est par la suite élargi pour englober les problèmes des producteurs de légumes. Aujourd'hui, les travaux de recherche de la Station portent sur la production et la protection des cultures horticoles et sur les cultures oléoprotéiques. La Station a trois sous-stations; la première, située à Frelighsburg et d'une superficie de 134 ha, est consacrée à la culture des fruits et des petits fruits; la deuxième, située à L'Acadie et d'une superficie de 86 ha, est consacrée à la culture des légumes et des petits fruits en sol minéral; la troisième, située à Sainte-Clothilde et d'une superficie de 32 ha, est consacrée à la culture de légumes en sol organique. De plus, la Station a la responsabilité de la Ferme expérimentale de L'Assomption et sa sous-station de Lavaltrie, d'une superficie de 105 ha.

La Station a pour responsabilité d'effectuer des travaux de recherche en horticulture sur la production et la protection organisés sous des programmes pluridisciplinaires: arbres fruitiers, petits fruits, légumes et plantes oléagineuses. Les disciplines représentées sont: entomologie, phytopathologie, nématologie, malherbologie, physiologie, chimie des pesticides, toxicologie, biologie moléculaire des plantes, génie aéronautique et mécanique.

Le mandat de la Ferme expérimentale de L'Assomption a deux objectifs principaux; l'un est la valorisation des sols sablonneux laissés partiellement libres par la diminution de la culture du tabac jaune; l'autre est le développement de rosiers rustiques à floraison soutenue et l'identification des zones d'adaptation d'espèces ligneuses ornementales.

La Station de recherches emploie 24 professionnels sur un personnel de 74 employés avec un budget d'opération annuel de 910 000 $. La Ferme expérimentale de L'Assomption et sa sous-station à Lavaltrie emploient 6 professionnels assistés de 15 autres employés avec un budget d'opération annuel de 240 000 $.

Pour de plus amples renseignements, s'adresser à: Station de recherches, Agriculture Canada, 430, boulevard Gouin, C.P. 457, Saint-Jean-sur-Richelieu, Québec, J3B 6Z8; tél. (514) 346-4494. Ferme expérimentale de L'Assomption, s'adresser à: M. Fernand Darisse, Agriculture Canada, 801, route 344, C.P. 3398, L'Assomption, Québec, J0K 1G0; tél. (514) 589-4775.

Pierre Martel
Directeur intérimaire

CULTURES FRUITIÈRES

Protection hivernale des fraisiers. Des rangs de fraisiers recouverts à l'automne d'une bâche plastique ont produit plus de fruits en saison que les rangs protégés ou non par de la paille hachée. Quand la bâche a été enlevée le 19 mai, la production des quatre premières cueillettes a été plus élevée que lorsque celle-ci avait été enlevée au cours des deux premières semaines de ce mois. La maturité des fruits a été avancée sous bâche plastique par rapport à la régie avec ou sans paille. On n'a remarqué aucun dommage hivernal dans les divers rangs sous observation.

Effets de traitements insecticides appliqués au stade bouton rose contre l'hoplocampe de la pomme. Le Québec est à ce jour la seule province canadienne qui a un problème d'hoplocampe (*Hoplocampa testudinea*) dans ses vergers commerciaux. Au cours d'études effectuées en 1986 à la ferme de Frelighsburg, nous avons traité (le 7 mai 1986, soit au stade bouton rose) un groupe d'arbres avec du Ambush 25WP.

On a dénombré trois fois plus d'hoplocampes en-dessous des arbres traités qu'en-dessous des arbres non traités. Ce type d'approche serait vraisemblablement efficace avec des produits ayant un effet rapide («knockdown effect») telles les pyréthrinoïdes. En 1988, nous avons fait une seconde expérience pour connaître l'effet d'un traitement au Ambush 500EC (i.a. à 212,5 g/ha) en évaluant les dommages primaires et secondaires causés aux fruits. Les traitements ont été effectués au stade du bouton rose, le 19 mai 1988.

Après la chute de juin, il y avait significativement plus de fruits ayant des dommages primaires dans les parcelles traitées au Ambush. Il est donc maintenant établi qu'un traitement effectué à l'aide d'une pyréthrinoïde au stade du bouton rose a un effet insecticide certain contre les populations d'hoplocampe du pommier.

De tels traitements doivent cependant être considérés comme étant complémentaires à ceux qui sont effectués au calice. Il convient toutefois de rappeler qu'au début de l'année 1988, aucun insecticide n'était homologué contre cet insecte au Canada.

Résistance à la tavelure chez le pommier. De 1971 à 1978, le programme d'amélioration génétique du pommier a généré 1 950 sélections résistantes à la tavelure. Dans ce programme, les cultivars Lobo, McIntosh, Cortland, Melred et Quinte ont servi de parents femelles avec quelques cultivars résistants à la tavelure comme le Macfree, le Trent et le Prima. Jusqu'à présent, 65 sélections ont été retenues pour effectuer des observations ultérieures plus poussées. La rusticité des pommiers de ces sélections ainsi que leur capacité à rapporter ont été enregistrées annuellement. De même, on a évalué la date de cueillette optimale des fruits, leur grosseur, leur coloration, leur fermeté, leur teneur en sucres et leur aptitude à la conservation.

Dans des parcelles d'essais avancés établies en 1988, 19 sélections ou cultivars résistants à la tavelure sont maintenant évalués en prenant la McIntosh comme point de comparaison. Tous les arbres de cet essai ont comme porte-greffes le M.M.106. Le type de croissance du pommier, sa susceptibilité au mildiou, la longueur de sa période de juvénilité ainsi que sa vigueur de croissance sont à l'étude dans ces parcelles.

CULTURES MARAÎCHÈRES

Construction d'une librairie génomique du doryphore de la pomme de terre. Le doryphore de la pomme de terre est le principal ravageur de la pomme de terre et il prend de plus en plus d'importance à mesure que son niveau de résistance aux insecticides augmente. La construction d'une carte génétique détaillée du doryphore permettra de vérifier si cette résistance aux insecticides est causée par des variations génétiques.

L'ADN chromosomal du doryphore a été isolé et ensuite récupéré. Après purification, l'ADN a été digéré à l'aide d'enzymes de restriction. Les fragments d'ADN du doryphore ont été insérés à l'intérieur de deux vecteurs plasmidiques par une ligation enzymatique. Deux vecteurs ont été utilisés afin de comparer leur efficacité. Le rendement en ADN obtenu de l'isolation est de 77 µg/g d'insecte. Cet ADN est de haut poids moléculaire et sa digestion par enzyme de restriction est facile.

Le clônage nous a permis de constater qu'il était possible d'insérer des fragments d'ADN de doryphore dans l'*Escherichia coli* et de pouvoir ainsi construire une librairie génomique du doryphore de la pomme de terre. Cette étape n'est que la première menant à l'établissement d'une carte génétique détaillée du doryphore.

Le temps de développement du nématode des nodosités en sol organique. Le nématode des nodosités *Meloidogyne hapla* est un ravageur important dans les sols organiques du sud-ouest du Québec.

L'étude s'est poursuivie sur 2 années consécutives à la Ferme expérimentale de Sainte-Clotilde. Au total, huit semis de laitue du cultivar Ithaca ont été faits en microparcelles infestées. Les températures de l'air et du sol ont été enregistrées pendant toute la durée de l'expérimentation. Les données de température de l'air ont été exprimées en degrés-jours cumulés à partir des températures moyennes journalières supérieures à 5 °C. Pour les données de température du sol, les unités thermiques heures, où une unité thermique est égale à un degré celsius supérieur au seuil de 5 °C pendant une heure, ont aussi été cumulées de la date de semis à un stade de développement donné du nématode.

Il a fallu une moyenne de 540 degrés-jours ou 9 761 unités thermiques heures pour que la larve hivernante de 2e stade se développe en femelle mature en début de ponte. Une moyenne de 909 degrés-jours ou 17 012 unités thermiques heures ont été nécessaires pour compléter un cycle complet, soit du second stade larvaire au second stade larvaire de la nouvelle génération.

En faisant référence à ces données, il sera maintenant possible de prédire, avec une précision connue, la date à laquelle le nématode des nodosités atteindra un stade de développement donné. De la même façon, on pourra connaître la date avant laquelle il sera

préférable de faire la récolte pour empêcher le nématode de se reproduire. En prenant soin de bien détruire tous les résidus de plante au champ, on aura ainsi trappé et tué des millions de nématodes dans les racines qui ne se reproduiront pas.

Influence de la dose et de la source d'azote sur la nutrition en oligo-éléments et l'incidence du «coeur creux» chez le brocoli. L'objectif de cette étude était de déterminer si la source et la dose de N ont une influence, d'une part sur l'existence de la tige creuse et d'autre part, sur le contenu en oligo-éléments des nervures centrales du brocoli (*Brassica oleracea* L. spp. *italica* Plenck 'Green Valiant'). Quatre sources de N, i.e., NH_4NO_3, $Ca(NO_3)_2$, $(NH_4)_2SO_4$ ou $CO(NH_2)_2$, ont été évaluées en combinaisons factorielles avec des doses de N de 75, 150 ou 225 kg/ha. L'effet de la dose de N sur la concentration en B des nervures récoltées à la mi-saison a été fonction des conditions de l'année courante; ce qui est le cas également des symptômes du coeur creux. Aucune relation n'a toutefois pu être décelée entre l'importance du coeur creux et la concentration en B, pas plus qu'avec aucun autre élément mineur étudié. Par ailleurs, la présence de N nitrique (NO_3) a diminué la concentration en Mn particulièrement en 1986. L'augmentation de la dose de N a agi corrélativement sur la concentration en Mn et Zn.

Mode d'irrigation et contenu en urée de la solution fertilisante pour plants maraîchers en mini-mottes. On a comparé l'irrigation par aspersion à l'irrigation souterraine avec des solutions nutritives complètes, contenant 0 % ou 50 % d'urée, sur la culture de plants maraîchers en mini-mottes. Les espèces étudiées étaient le brocoli, le céleri et la laitue.

L'irrigation par aspersion a favorisé la croissance de la partie aérienne de toutes les espèces, mais la présence d'urée a été sans effet significatif. Le type d'irrigation a été pratiquement sans effet sur la composition minérale du brocoli alors que, chez le céleri et la laitue, les concentrations des tissus en azote et phosphore étaient nettement inférieures avec l'irrigation souterraine. Celle-ci a aussi généralement appauvri le contenu en éléments de l'extrait saturé du milieu nutritif (SME) des plants de céleri. Selon l'espèce, la présence d'urée a augmenté la concentration en azote, phosphore, potassium, calcium, magnésium, manganèse ou zinc de la partie aérienne. Les résultats témoignent d'importantes différences interspécifiques quant à l'effet du type d'irrigation et de la présence d'urée.

Interaction entre l'Ethéphon et la fertilisation azotée sur la productivité de la tomate de champ. Dans ce projet, nous avons étudié l'influence de la dose d'azote, de la dose d'Ethéphon et de sa date d'application sur la productivité de la tomate de conserverie.

L'année 1987 a été exceptionnelle avec une production de fruits (toutes catégories) de 80,7 t/ha dont 57,7 t/ha de fruits n° 1, soit le double des années 1986 et 1988. La quantité de fruits n° 2 au mûrissement insuffisant n'a pas varié en fonction de l'année, et le rendement a été d'environ 6,2 t/ha. Nous avons appris que l'application tardive d'Ethéphon favorise le grossissement des fruits puisque la masse des fruits de toutes catégories s'accroît de 8 %. Cette augmentation est surtout associée à une récolte 60 % plus abondante de fruits n° 2 au mûrissement insuffisant et 31 % plus grande de fruits restés verts. Toutefois, l'application précoce donne en moyenne un rendement de 6 % supérieur de fruits n° 1, de la meilleure qualité. Ces fruits sont alors plus nombreux, mais plus petits. La dose d'Ethéphon de 3,5 L/ha est nettement suffisante pour la plupart des situations; il est inutile de dépenser davantage pour améliorer le rendement. Pour récolter des fruits de la meilleure qualité possible, l'application précoce d'Ethéphon est en général préférable à l'application tardive bien que cette dernière procure plus de fruits n° 2 qui restent vendables.

La quantité d'azote appliquée n'a eu aucun effet sur les rendements en fruits de classe n° 1. En augmentant la dose, on a obtenu moins de fruits n° 2 au mûrissement insuffisant, mais davantage de fruits verts de rebuts. Ces effets de la dose d'azote ont été les mêmes, peu importe l'année considérée. Nos travaux confirment le doute qui s'exprimait chez les producteurs quant à la recommandation actuelle de fertiliser à raison de 135 kg/ha de N. Nous avons obtenu des rendements de fruits n° 1 aussi bons avec la dose de N à 45 kg/ha.

La fertilisation en potassium est sans doute la plus directement reliée à la qualité et au mûrissement de la tomate et le contenu du sol en potassium intervient dans l'interprétation des résultats.

CULTURES MARAÎCHÈRES

Évaluation de cultivars de soja. La production de soja au Québec a couvert 10 500 ha en 1988, une augmentation de 62 % par rapport à l'année précédente. L'évaluation de cultivars de soja pour le Québec s'est poursuivie en 1988. Au total, 42 cultivars de soja hâtif et 63 cultivars de soja ayant une maturité de 2 600 unités thermiques-maïs ont été évalués. La saison sèche a semblé activer la maturité avec des plants plus petits que les années précédentes et un rendement légèrement inférieur. Cet essai a contribué à l'enregistrement du cultivar de soja XP-0282.

Évaluation de cultivars de canola. Cette évaluation s'est poursuivie en 1988 sur le canola de printemps et le canola d'hiver. Au total, 30 cultivars de canola d'hiver ont été évalués. Ils ont bien survécu à l'hiver (50–90 %) à cause du terrain bien drainé à la ferme expérimentale de L'Acadie. Pour le canola de printemps, 49 cultivars ont été évalués. La sécheresse a affecté la croissance à un point tel que la hauteur moyenne des plants a diminué de 20 % et que les rendements ont été inférieurs d'environ 15 % à ceux de l'année précédente.

Inventaire des insectes ravageurs du canola. L'inventaire des insectes nuisibles au canola de printemps et canola d'hiver à l'aide de pièges a permis la capture, particulièrement en mai et juin, des mêmes espèces qu'en 1987, soit l'altise des crucifères, *Phyllotreta cruciferae* (Goeze), l'altise du navet, *Phyllotreta striolata* (F.), l'altise du houblon, *Psylliodes punctulata* Melsh., le nitidule *Meligethes nigrescens* Stephens et le puceron du chou, *Brevicoryne brassicae*. Cependant, comme pour les deux dernières années, aucun dommage d'ordre économique n'a été observé dans les parcelles expérimentales de la ferme de L'Acadie.

Impact de cinq méthodes culturales sur le maïs-grain et la pyrale. Pendant 5 ans (1977–1981), à la ferme de L'Acadie, on a évalué cinq façons culturales sur deux cultivars sous différentes intensités d'infestations de pyrale, soit sous infestation naturelle, une infestation artificielle et une infestation artificielle suivie d'un traitement unique d'insecticide granulé. Les façons culturales étaient la méthode classique, un labour-hersage à l'automne, un labour-hersage au printemps, un semis sur sillon butté et enfin, le non-travail du sol.

Les critères de comparaison des résultats utilisés ont été la brisure de la tige au-dessus et au-dessous de l'épi, le rendement et l'humidité des grains à la récolte. La méthode classique et le labour-hersage faits au printemps ont donné des rendements significativement plus élevés pendant les 5 années, chacune étant aussi moins affectée pendant les années sèches. Le labour-hersage au printemps et le semis sur billon ont réduit significativement les dommages causés par la pyrale aux plantes bien qu'il n'y eut aucun effet de réduction de rendements causé par la pyrale. Le nombre de jours entre le semis et 50 % des plantes en floraison a été relié positivement avec l'humidité des grains à la récolte, la méthode classique favorisant une moins grande humidité, ce qui permet de réduire d'autant les coûts de séchage. Le labour-hersage au printemps a réduit significativement les attaques de la maladie cryptogamique *Gibberella zeae*. En somme, il semble que la méthode dite classique réponde bien aux exigences des producteurs de maïs-grain.

CHIMIE ET GÉNIE

Construction d'un système d'entreposage en atmosphère contrôlée pour des fins expérimentales. Un système d'entreposage individuel en contenants étanches de 110L (mini-chambre) a été développé. Ce système d'entreposage permet l'utilisation des entrepôts réfrigérés déjà existants qui peuvent contenir 14 mini-chambres. La quantité de produit à utiliser pour chaque essai a été réduite par un facteur de cent par rapport aux chambres existantes sans affecter significativement la valeur des résultats expérimentaux.

Les deux types de systèmes de contrôle suivants ont été utilisés pour maintenir la concentration des gaz au niveau désiré à l'intérieur des mini-chambres: un système passif à membrane semi-perméable et un système actif incorporant un automate programmable qui permet d'opérer l'ouverture et la fermeture des valves électriques qui servent à contrôler le lessivage du CO_2 et l'ajout du O_2. Des essais ont servi à déterminer les conditions d'entreposage à utiliser. On a construit huit chambres pourvues de système passif qui servent à l'entreposage de nouvelles variétés de pommes. On a également construit

18 chambres équipées d'un système actif qui sont destinées à la recherche sur l'entreposage du chou et de la pomme. Le temps nécessaire aux analyses des gaz est vingt fois plus rapide grâce au système semi-automatique d'analyse des gaz qui a été développé dans ce projet.

Pulvérisateur pour parcelles expérimentales. Un pulvérisateur a été développé afin d'appliquer des herbicides sur les parcelles expérimentales. On a comparé les temps d'opération de l'ancien et du nouveau pulvérisateur. Les opérations sont plus rapides avec le nouveau pulvérisateur. De plus, le nouveau système ne requiert qu'un seul opérateur dans le champ puisque les herbicides sont mesurés en laboratoire la veille plutôt que par un second technicien dans le champ, comme c'était nécessaire avec l'ancien système.

On a aussi comparé la qualité de rinçage des deux pulvérisateurs. Pour l'ancien système, il n'y a eu aucune différence significative entre une suspension et une poudre mouillable pour la quantité d'herbicide mesurée après rinçage. Pour le nouveau système, il y avait une différence significative entre les formulations. La poudre était plus difficile à rincer. Un second rinçage était nécessaire pour abaisser la concentration de l'eau de rinçage à moins de 0,1 % de la concentration de la solution initiale. Un seul rinçage était suffisant pour l'ancien système et avec la suspension pour le nouveau système.

FERME EXPÉRIMENTALE DE L'ASSOMPTION

Plantes ornementales

Propagation de plantes. La méthodologie pour la multiplication in vitro de douze cultivars de *Prunus* ornementaux a été développée. Ces cultivars sont le cerisier des sables (*P. besseyi* 8601, *P. besseyi* Lett.), le prunier pourpre des sables (*P. cistena* Hansen), la cerise naine d'Europe (*P. fruticosa* Pall.), le cerisier à grappes (*P. padus* Men. Schubert, *P. padus* Wateri, *P. padus colorata*), le cerisier sauvage (*P. pensylvanica* L.), le faux amandier (*P. glandulosa* 'Rosea' et *P. triloba* 'Multiplex'), l'amandier nain (*P. tenella* 'Firehill') et le cerisier-prune (*P. cerasifera* W7). Cette méthode de multiplication permet de produire 6 à 13 plantules à partir d'un bourgeon axillaire pendant une période de 6 semaines. Le taux de multiplication après la période initiale de 6 semaines devient alors logarithmique pour la ou les périodes suivantes. Ces résultats permettront à l'industrie des pépinières de propager rapidement des clones et de nouveaux cultivars de *Prunus*, d'exclure la nécessité de greffer dans certains cas (prune) et de réduire l'incidence des maladies communes aux *Prunus*.

Dispersion des graines de cardamine de Pennsylvanie. La cardamine de Pennsylvanie est souvent observée dans les pépinières de plantes ornementales que l'on fait croître en contenants. Une des caractéristiques de la cardamine est que ses graines sont mécaniquement dispersées par l'éclatement de la silique. La projection des graines se produit par la séparation subite des valves et par leur enroulement énergique, ne laissant qu'une fausse cloison. On a entrepris une expérience en serre en 1987 afin d'évaluer la capacité de dispersion des graines de cardamine de Pennsylvanie. La distance de projection moyenne des graines est de 46,5 cm; la distance minimale observée est de 0,1 cm et la distance maximale est de 148,0 cm. Cette observation peut avoir une incidence sur la décision d'intervention en vue de réprimer cette mauvaise herbe.

Capacité de régénération des rhizomes de la rorippe sylvestre. La rorippe sylvestre est une mauvaise herbe vivace qui infeste de nombreuses pépinières ornementales du Québec. On a entrepris une expérience en serre afin de déterminer la capacité de régénération de ses rhizomes. Le temps d'émergence et la biomasse totale (matière sèche) ont été mesurés. Seulement 2,5 % des rhizomes n'ont pas produit de plantes. Le nombre de jours requis pour émerger et la biomasse ont été significativement affectés par la longueur des rhizomes. En moyenne, les plantes ont pris de 10 à 19 jours pour émerger du sol. Le temps requis était inversement proportionnel à la longueur des rhizomes et la biomasse produite était proportionnelle à la longueur des rhizomes.

Cultures qui remplacent le tabac

Culture de l'asclépiade pour la production d'aigrettes. Ce projet avait pour but d'évaluer les effets de l'espacement, de la population, de la méthode d'établissement, de la fertilisation et des défanants au champ sur le rendement en aigrettes. En 1988, chacun des plants établis par semis ou par transplantation a produit une

moyenne de 8,6 et 14,3 follicules respectivement. Le rendement moyen en follicules se situe aux environs de 859 722/ha pour une population naturelle de transplants et 740 000/ha pour une population naturelle semée. Seul l'éthrel s'avère un défanant acceptable pour l'asclépiade, car il n'affecte pas la maturité des follicules.

Évaluation d'espèces et de cultivars de plantes aromatiques, condimentaires et médicinales. On a établi des parcelles de plantes aromatiques annuelles et vivaces à la ferme expérimentale de L'Acadie en 1987 et 1988. Le rendement à l'hectare a été estimé d'après les rendements obtenus en parcelle. Les plantes étudiées étaient l'estragon, le rumex, la ciboulette, le thym, la bardane, la lavande, l'hysope, la menthe poivrée, la menthe verte, la livèche, le sauge, le chili, la valériane, la monarde, l'angélique ainsi que l'achillée mille-feuilles provenant de sept endroits différents. On a noté les dates de floraison de récolte et d'apparition d'insectes ou de maladies. Des échantillons ont été récoltés pour extraction d'huile ou de composés divers et des dosages de résidus de divers pesticides ont été effectués. Seules la menthe, l'achillée et la monarde semblent avoir du potentiel comme culture de remplacement du tabac.

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INTRODUCTION

The Delhi Research Station, founded on the Norfolk sand plain in southwestern Ontario in 1933, was initially established to conduct research on flue-cured tobacco. The station now conducts multidisciplinary research programs on tobacco for eastern Canada, and on alternative crops and the management of coarse-textured soils relative to long-term productivity for southwestern Ontario. Eight professionals from a total staff of 40 conduct commodity-oriented research to improve yield, quality, and efficiency of crop production. Research is carried out on a 60-ha site and at several off-station locations.

This report summarizes some of the results obtained in 1988. Further information can be obtained from the Research Station, Research Branch, Agriculture Canada, P.O. Box 186, Delhi, Ont. N4B 2W9; Tel. (519) 582-1950.

P. W. Johnson
Director

TOBACCO AND ALTERNATIVE CROPS

Production

Transplants, affected by partial freezing injury, could be decapitated to encourage an axillary bud to regain plant development and extension of the main growing axis. This management procedure provided significantly improved crop productivity compared with the replanting of damaged plants, should replanting be needed within approximately 2 weeks after normal transplanting.

Tobacco grown at 35 and 31°C, day and night temperature regimes, showed significantly reduced growth as well as morphological changes to the leaves. Return to 25 and 21°C promoted near normal growth of newly developing leaves, but the existing leaves did not recover. Preliminary data suggest that temperatures in excess of 30–35°C had a detrimental effect on tobacco growth under controlled environment conditions.

Genetics and plant breeding

A program to evaluate cultivars registered in the United States was conducted in 1988. Nine cultivars were compared with Delgold for agronomic, physical, and chemical characteristics.

Generally, the U.S. cultivars provided a bright, lemon-colored, clean-cured leaf. The quality index of three entries (Coker 371 Gold, NK5168, and Speight G102) were graded higher than the check cultivar. The data suggested that there was as much as a 10% variation in grade price between the entries tested ($3.60–$3.90/kg). Yields of all cultivars tested were from 10 to 25% less than Delgold (200–600 kg/ha), and days from planting to topping ranged from 3.5 to 7 days later. With the exception of Speight G102, all entries analyzed for nicotine were from 10 to 40% less than Delgold. In summary, the American cultivars tested in 1988 did not perform within the parameters established for recommended cultivars grown under Canadian agro-climatic conditions.

The 1988 crop was produced with 97% Delhi-bred cultivars. Delgold was still the dominant variety grown on 82% of the hectarage; Delliot and Candel each on 6%; and Delhi 76, Newdel, and Nordel collectively on 3%.

Chemistry

A field experiment was conducted in 1981 and 1982 on Fox loamy sand to study the effects of a number of harvested leaves on selected agronomic and chemical characteristics of flue-cured tobacco, *Nicotiana tabacum* L. The cultivar Delgold was topped at 12, 15, and 18 leaves; it was topped at 18 leaves, with either three or six of the lower leaves removed. Reducing the number of harvested leaves had a negative impact on yield and returns, regardless of whether the leaf number was reduced by lower topping or by removing the bottom leaves. Differences in chemical composition among treatments for phytosterols, green pigments, fatty acids, polyphenols, organic acids, hexane extracts, duvatrienediols, reducing sugars, and total alkaloids followed changes of composition with stalk position, although differences were typically smaller than expected.

A field experiment was conducted from 1983 to 1987 on a Fox loamy sand soil to study the effects of transplanting date on selected agronomic, physical, and chemical characteristics of flue-cured tobacco, *Nicotiana tabacum* L. Tobacco plants of the cultivar Delgold were transplanted at 3- to 5-day intervals, starting in mid May and continuing for seven to nine planting dates. Delaying transplanting decreased yield, returns, total alkaloids, hexane extracts, lamina weight, and percentage of lamina. Delaying transplanting also increased the chlorophyll content of the leaf but had no effect on reducing sugars and only reduced grade index late in the planting season.

Protection

Monitoring studies. Larvae of dark-sided, striped, and sandhill cutworms increased in abundance from 1987, and population levels of 12–34 larvae per 100 plants were present in many tobacco fields in 1988. The high populations were attributed to the warm, dry spring, which was favorable for cutworm development.

Aphids on tobacco have been correctly identified as the tobacco aphid *Myzus nicotianae* Blackman, not the green peach aphid, *Myzus persicae* (Sulzer), as previously thought. Two color forms, green and red, are present. In 1988 aphid populations were on the decline and were not as severe and widespread as in 1987. The population density ranged from 260 to 1224, with an average of 725 aphids per leaf.

Chemical control. A 3-year study on the effects of alphamethrin, cyhalothrin, fluvalinate, and cypermethrin on cutworms and on yield and quality of flue-cured tobacco revealed that all insecticides were effective in controlling cutworms. The results from physical and chemical analyses of cured tobacco leaves indicated that the insecticide treatments had no adverse effects and increased both yield and grade index as compared with the untreated check.

Preliminary studies of frost control materials did not show any promise for tobacco transplants under controlled conditions. At −5 to −5.5°C, damage was present on control and treated plants. Field studies were established by 4 May 1988, but the last frost was on 25 April 1988.

Weed control

The experimental postemergence graminicides sethoxydim, fluazifop-*p*-butyl, Excel, clethodim, and Assure were evaluated over 3 years for their effects on the grade index, yield, return index, total alkaloid, and total reducing sugar content of flue-cured tobacco. These herbicides had no deleterious effect on the measured agronomic and chemical characteristics at the rate range tested.

Field crops

A number of alternative crops are being investigated including peanuts, evening-primrose, kenaf, amaranth, quinoa, sweet white lupine, and guayule.

Three hundred and fifty hectares of peanuts were produced in 1988, with pod yields ranging from 1200 to 2800 kg/ha. The wide range was a result of extremely variable moisture patterns. The two new peanut cultivars that were granted interim registration in 1987 have now been fully registered. Establishing consistent markets is still the main problem with peanuts.

Forty-one biotypes (native clones) of evening-primrose are under evaluation. Seed yields ranged from 170 to 740 kg/ha, oil content ranged from 16.6 to 26.4%, and gamma linolenic acid (GLA) content ranged from 6.0 to 13.0%.

Mean dry-matter yields of kenaf were 8.1 t/ha in 1987 and dropped to 3.7 t/ha in 1988. Drought-like weather conditions in 1988 were the cause of this decline.

Four cultivars of amaranth tested in 1988 produced seed yields of 148 to 312 kg/ha.

Three quinoa cultivars that were tested flowered but failed to produce any seed.

Eight sweet white lupine cultivars yielded 317–410 kg/ha. Sweet white lupines do not appear to be adapted to this area of 3000 corn heat units (CHU).

Five cultivars of guayule were transplanted to the field in the spring of 1987. Guayule requires two to three growth seasons to produce rubber cells. None of the five cultivars survived the winter season of 1987–1988, and therefore the crop has been abandoned as a potential alternative crop.

Insect survey. Heavy infestations of the potato leafhopper, *Empoasca fabae* (Harris), occurred on peanuts from late June to late August in 1988. The population density of the potato leafhopper nymphs ranged from 27 to 85 for every five plants. Insecticide sprays were used by all growers, and most fields were sprayed twice—once in early July and once in early August.

Weed control. Field experiments were conducted over a 3-year period to evaluate the efficacy and crop yield response of certain preemergence herbicides for the control of silky bentgrass, *Apera spica-venti* (L.) Beauv., in fall rye and winter triticale. In rye, silky bentgrass was controlled with a single application of isoproturon with active ingredient (a.i) at 1–2 kg/ha, CHEM HOE 135 with a.i. at 1 kg/ha, trifluralin with a.i. at 0.4–0.6 kg/ha, chlorsulfuron with a.i. at 0.012–0.036 kg/ha, and metsulfuron with a.i. at 0.006–0.024 kg/ha. None of these treatments adversely affected rye yield. In a farm demonstration-sized trial on winter triticale, silky bentgrass was controlled with a single preemergence application of trifluralin with a.i. at 0.4 kg/ha, and crop yield was unaffected.

Horticultural crops

Roots of sweet potato were observed to contain approximately 16–24% dry weight, and approximately 40% starch before curing. Starch levels decreased during curing and storage. Reducing sugars and total sugars were approximately 6 and 11%.

A 2-year field survey of insect pests of sweet potatoes has shown that there are no economically important insect pests. No insecticide application is needed at present for growing sweet potatoes in the Delhi area.

Tomatoes are susceptible to injury from a great many genera and species of plant-parasitic nematodes. In 1987 research was initiated to determine if row fumigation of a Fox loamy sand soil infested with root lesion *Pratylenchus penetrans* nematodes would produce an economic response in the yield or quality of paste tomatoes. Plant size and yield of red fruit were the only crop parameters significantly affected by fumigation. Yields in 1988 were increased by 12.4 t/ha, resulting in an increase of $1275.32/ha (based on an option A contract of $123.01/t and a cost of fumigation of $250/ha) in gross returns.

Populations of the overwintered Colorado potato beetle, *Leptinotarsa decemlineata* (Say), were high on tomatoes in 1988. Heavy infestations occurred from late May to mid June. The population density ranged from three to eight beetles and one to three egg masses per plant. Damage was severe, and applications of insecticide were needed for effective control.

Chemical control. Results from 3 years of investigations revealed that acephate transplant-water treatments were effective for control of several early-season insect pests, Colorado potato beetles, cutworms, root maggots, and aphids on tomatoes for 2–6 weeks, depending on the species and the rate of application. The high rate of acephate appeared to cause brown and burned spots on the leaves but no adverse effects on plant growth.

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Research Station, Harrow, Ontario

PROFESSIONAL STAFF

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J.A. Stone, B.S., M.S., Ph.D.	Soil physics
A.H. Teich, B.A., B.S.A., M.Sc., Ph.D.	Winter wheat breeding
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Departure

F. Kappel, B.Sc.(Agr.), M.Sc., Ph.D. Transferred to Research Station, Summerland, B.C. 6 February 1988	Orchard management

EXTENSION SERVICES[6]

J.C. Fisher, B.S.A.	Greenhouse and fresh market vegetables
L.A. Huffman, B.Sc.(Agr.)	Fruit crops and asparagus

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[1] Seconded from Libraries Division, Corporate Management Branch.
[2] Seconded to the Soil and Water Environmental Enhancement Program.
[3] Returned from educational leave 1 April 1988.
[4] On leave without pay, 1 October 1988 to 1 October 1989.
[5] Returned from educational leave 13 June 1988.
[6] Provided by Ontario Ministry of Agriculture and Food.

INTRODUCTION

The research station at Harrow was established in 1959 to serve the agriculture and food sector in southwestern Ontario. The station has close links with industry through direct interactions with growers, processors, and farm suppliers and through numerous joint committees involving these groups. Cooperative research is carried out with private industry and universities in southwestern Ontario. Links with the Ontario Ministry of Agriculture and Food (OMAF) are maintained through jointly funded research activities with OMAF organizations, agreements regarding areas of research, cooperative activities in the Soil and Water Environmental Enhancement Program, and the location of OMAF personnel at the station.

In support of departmental and branch missions, the station's mandate is to improve the yield, quality, and efficiency of crop production. Crops under study include soybeans, field beans, soft white winter wheat, grain corn, field and greenhouse vegetables, and stone and pome fruits. Through multidisciplinary commodity teams the following areas of basic and applied research are emphasized: crop improvement using breeding and genetics to create new germ plasm and cultivars with improved agronomic or horticultural characteristics, resistance to pests, and suitability to environmental conditions; crop protection using chemical, biological, and cultural methods to control diseases, insects, and weeds, with emphasis on the management of pest populations, development of integrated crop management systems, and improvement of environmental quality; and crop and soil management using improved cultural practices, cropping systems, fertilizer practices, and tillage systems to improve soil structure and fertility, to reduce soil erosion, and to improve water quality.

The station has a person-year complement of 114, including 29 researchers, with a total budget of $5 million of which $0.9 million is designated for support and services. Field operations are carried out at three locations. The main station and the Ridge Farm, comprising 131 ha and 21 ha, respectively, are representative of sandy loam soils. The Hon. E.F. Whelan Experimental Farm is located in the centre of Essex County on 57 ha of Brookston clay soil.

This report provides brief summaries of results obtained in 1988. Further information can be obtained by writing to the Research Station, Agriculture Canada, Harrow, Ont. N0R 1G0; Tel. (519) 738-2251.

C. F. Marks
Director

FIELD CROPS

Corn

Effect of simulated rootworm damage on yield of grain corn. Roots of field corn were pruned weekly to simulate damage by larvae of the western corn rootworm. Reduction in yield of grain was highly correlated with the amount of reduction of root volume. Removal of as much as 22% of roots in each of the first 3 weeks did not affect yield, but more frequent pruning to this extent did reduce yield. The data indicate that if soil moisture is adequate for plant growth, yield of corn is not reduced by a loss of root volume for a limited period. Therefore, application of insecticides for control of corn rootworm larvae can be delayed until after the first cultivation of the crop rather than applying the insecticide at planting as a preventive practice.

Forages and the aggregation of a clay loam soil. The aggregating ability of alfalfa, sweetclover, slender wheatgrass, timothy, reed canarygrass, crested wheatgrass, tall fescue, Austrian winter pea, and red clover was evaluated in an 80-day growth-root experiment. Reed canarygrass and sweetclover showed the most increase in aggregate stability. However, improvements in aggregation generally increased with the extent of root development. Although the frequency of vesicular-arbuscular mycorrhiza varied between forages, it was not associated with improvements in aggregation. The results indicate that the root density and rate of development of a forage may have the biggest impact on short-term improvements in aggregation and should be considered when selecting a forage for inclusion in a cropping system.

Protection. Metolachlor and atrazine, which are used to control weeds in corn, do not provide control of the common weed, velvetleaf. Metribuzin has been a key component in the control of velvetleaf in soybeans and was therefore proposed for use in corn. When a low rate of metribuzin (0.3 kg/ha) was added to a mix of metolachlor and atrazine, velvetleaf control was shown to improve from less than 50% to greater than 85%. Selected hybrids were evaluated for injury to metribuzin and resulted in the registration of the use of metribuzin in combination with metolachlor and atrazine for velvetleaf control only in specific corn hybrids.

Soybeans

Diseases. The pathogens *Rhizoctonia solani*, *Fusarium oxysporum*, and *F. graminearum* were the fungi most frequently isolated from the roots and stems of plants from areas of the field showing stunting of soybeans. Stunting of plant growth was most severe when all three organisms were present. Consequently, all three organisms must be considered when developing future control measures. Cultivars resistant to the above fungi are not yet available.

A total of 265 soybean mosaic samples were collected, and nine virus strains were characterized. Two new strains (H1 and H2) were found in addition to the seven strains (G1 to G7) reported from Illinois. Strain H1 caused severe necrotic symptoms in many Ontario cultivars. A new dominant gene (Rsv_3) for resistance was discovered. Incorporation of any two of the three major genes (Rsv_1, Rsv_2, and Rsv_3) into a cultivar should reduce the risk of soybean mosaic virus (SMV) disease.

The incidence of sclerotinia white mold was shown to be related partly to soybean maturity, with earlier maturing cultivars tending to have less disease. Cultivars requiring less than 2550 heat units (HU) to mature had a low incidence. Maple Donovan, requiring 2750 HU, and S1346, requiring 2900 HU, had less white mold than cultivars of similar maturity. There was no effect of row spacing on the incidence of white mold. If a full-season cultivar with suitable resistance is not available for use in *Sclerotinia*-infested fields, growing an earlier maturing cultivar in narrow-row culture could be a cost-effective way of decreasing the incidence of disease, reducing inoculum buildup, and obtaining high yield.

Herbicide tolerance. Soybeans grown under hydroponic conditions in a greenhouse showed that cultivars with the *Rps1-k* gene for *Phytophthora* resistance had marked tolerance of metribuzin herbicide. In 2 years of field tests on a clay soil, Elgin showed an inverse relationship between yield and rate of metribuzin, with active ingredient (a.i.) of up to twice the recommended rate of 1.12 kg/ha. The yield of Elgin 87, which carries *Rps1-k*, was not significantly affected by the increasing rates of metribuzin. This improved tolerance is expected to be of benefit to growers when variation in soil type within a field or heavy rainfall would normally result in crop injury and loss from metribuzin application.

Field beans

Breeding and genetics. The resistance of cultivars of field bean to bean common mosaic virus is due to the presence of the I gene. Unfortunately, this gene results in a hypersensitive type of reaction, which kills the plant. Susceptibility to the disease is due to the presence of the gene BC_3. However, several white bean lines have been selected that carry both genes and are resistant to the virus without the hypersensitive reaction. These lines provide germ plasm for the development of new disease-resistant cultivars.

Several white bean lines have been obtained with improved resistance to common bacterial blight (*Xanthomonas phaseoli*) by transferring resistance from various germ plasm sources. Resistance in A8-40, a bean mutant for common blight, delayed (but did not prevent) development of leaf blight infection in greenhouse screening tests. Germ plasm introduced from Centro Internacional d'Agricultura Tropical was found to be resistant to local isolates of common leaf blight.

Common blight. Epidemiological studies of bean blight are hampered by the lack of reliable plating media, among other diagnostic tools. A selective medium using the addition of brilliant cresyl blue was developed for the common and fuscous blight bacteria based on starch retrogradation and inhibition of commonly encountered epiphytic and seed-inhabiting bacteria and fungi. The medium was found to be useful in seed plating assay and in monitoring epiphytic populations of blight bacteria. However, further improvements to increase its efficacy are needed.

Stem blight. A new stem blight was discovered. The disease appeared to be widespread in southwestern Ontario. Isolation and characterization yielded *Glomerella cingulata* (Stonem.) Spaulding & Schrenk and a pink *Colletotrichum* sp. yet to be identified. The disease thrived in mid- to late-growth stage. Pods above the affected stems usually died prematurely and seed set was greatly reduced. Foliar and pod infection were also common. Infected leaves developed brown to chocolate brown lesions on leaf veins and on interveinal tissues. Both fungi were seed-borne and capable of overwintering in plant debris in the field.

Wheat

Breeding and genetics. Ena, a soft white winter wheat (registration #2973), was released. Under field conditions it is less susceptible to scab and leaf rust than other cultivars of its market class grown in Ontario. Its low accumulation of the mycotoxin deoxynivalenol is a major advantage. In areas of southwestern Ontario with more than 2900 CHU, it yields within 1% of the highest yield cultivar.

FIELD VEGETABLES

Green peas

Root rot. Root rot severity increased with inoculum density in the field. At a given inoculum concentration, root rot severity increased slowly from 10 to 20°C and exponentially from 20 to 35°C. Water stress promoted fusarium wilt and plant death. Excessive water favored fusarium root rot and damping-off. Liming of soil to bring soil pH to about 6.5 prompted saprophytic bacterial growth, particularly *Bacillus* and *Pseudomonas* spp., which lead to a competitive decrease in population of root rot fungi. Green manuring of soil reduced the population of root rot fungi by 30 to 55% and lessened the incidence and severity of pea root rots.

Peppers

Infestation of peppers by the European corn borer. Four cultivars of field peppers were artificially infested with egg masses of European corn borer after plants were thinned to a selected fruit number and size. Larval survival and establishment were low when compared with initial rates of egg infestation. Damage to cultivars of sweet pepper by larvae of the borer was greater than was damage to the pungent cultivars of hot pepper. Feeding damage to cultivars tested was more common among large or mature fruit than among small or immature fruit. It appears that early-season damage to small, immature pepper fruit is less likely because of high larval mortality and the difficulty that larvae have in finding the small developing fruit on the plant.

Insect host-plant resistance. Laboratory choice tests showed that host-plant preferences of the egg-laying females of pepper maggots were generally independent of the original host, suggesting that flies may move freely from weeds to crop plants. Field and laboratory studies showed that pepper varieties bearing dark green fruit were more susceptible to pepper maggot damage than those bearing fruit of other colors. Bell and cherry-shaped peppers were preferred by egg-laying females over banana-type peppers. Pungency of peppers did not affect preferences by the ovipositing females. However, larval survivorship was lower in more pungent peppers. Pepper maggot females oviposited in the fruit of a wide range of solanaceous plants, including tomatoes, when fruit was removed from plant foliage. However, leaves, particularly those of tomato, deterred oviposition on intact plants. Identification of characteristics of fruit and foliage of solanaceous plants that reduce adult egg-laying and larval survivorship could be important to breeding long-term host-plant resistance to insect pests of peppers.

Pest monitoring. The pepper maggot, *Zonosemata electa*, is a major pest of peppers in Essex County. A degree-day model for predicting emergence of the adults was developed from laboratory and field studies. Adult survival and times of emergence from overwintered pupae held at various constant temperatures were used to derive the base temperature (9.5°C) and the degree-days (602) required for 50% adult emergence. The model was validated by comparing predicted emergence times against observed events. The degree-day model greatly improved prediction of pepper maggot emergence over historically used calendar dates. Predicted times of 50% adult emergence were all within 1 day of the observed events. The accurate prediction of the adult emergence of the pepper maggot will enable extension personnel to inform growers of the optimum times for insecticide application.

Research Station, Harrow, Ont.

Tomatoes

Bacterial canker. Systemically infected seeds needed for studies on disease control were produced in the greenhouse by the technique of peduncle inoculation, which resulted in a uniformly high level of seed infection. However, the common method of seed extraction by fermentation reduced seed infection to various degrees, depending on extraction time. The use of pectinase over a period of 1 h provided a method of removing the gel coat from the seed and providing the seed with high levels of infection and germination for use in disease control experiments.

For 1988 field experiments on canker control, infected tomato seeds produced in the greenhouse were treated with (*1*) 0.6 *M* hydrochloric acid, (*2*) 0.6% (available chlorine) sodium hypochlorite, (*3*) 0.05% w/v *o*-hydroxydiphenyl. In seed plating assays the three seed treatments resulted in apparent eradication of the canker bacteria from the seeds, compared with 96% infection found in the untreated check. In the infected check, 36% of plants had cankers and 49% died. There was no plant mortality or canker in the *o*-hydroxydiphenyl treatment; no plant mortality but a very low (.01%) incidence of canker in the acid treatment and a 1% plant mortality; and 9% of the plants had cankers in the sodium hypochlorite treatment. At harvest in September, 62% of the remaining plants in the infected check and 17% in the sodium hypochlorite treatment had cankers compared with 0.6% in the acid and none in the *o*-hydroxydiphenyl treatments. There was a substantial reduction in the plant stand in the infected check (72%) and a moderate reduction in the sodium hypochlorite treatment (14%). The yield of tomatoes was significantly higher in the *o*-hydroxydiphenyl (33.25 t/ha) and acid (28.05 t/ha) treatments, and it was negligible in the infected check (1.45 t/ha).

Breeding. A major project was continued in 1988 to overcome the severe incongruity barrier that has prevented tomato breeders from making efficient use of the extensive genetic variability available in *Lycopersicon peruvianum*, including resistance to several important diseases, chilling tolerance, and improved solids level. Using three bridge lines and the embryo callus technique for rescuing interspecific hybrids, crosses were made with 11 of 15 new *L. peruvianum* accessions, including three cultivars of *L. glandulosum* and three cultivars of *L. humifusum*. This represents a major expansion in the range of *L. peruvianum* germ plasm available to the tomato breeder and brings to 24 the number of *L. peruvianum* populations accessed in the tomato breeding program.

Solanum lycopersicoides is tolerant of low temperatures relative to tomato or other *Lycopersicon* species. An intergeneric F_1 hybrid between *L. esculentum* and *S. lycopersicoides* was obtained that had completely sterile pollen, even following chromosomal doubling with colchicine. Using the *L. peruvianum* bridge line and embryo callus culture, hybrids involving *S. lycopersicoides*, *L. esculentum*, and *L. peruvianum* have been obtained. This material has about 33% viable pollen and is being backcrossed to adapted tomato lines.

Irrigation effect. An experiment was conducted to determine the effect of drip and sprinkle irrigation on processing tomato production. Five tomato cultivars (FM6203, H2653, H722, OH7814, and PUR812) were grown on Fox loamy sand. The 1988 growing season was extremely hot and dry. The total water deficit from May to August was 353 mm, as compared with a normal water deficit of 195 mm for the same period. Drip irrigation plots were irrigated three times a week from mid May to August, and sprinkle irrigation plots were irrigated four times. Both drip and sprinkle irrigation increased total marketable yields but reduced total solids of tomatoes, especially under drip irrigation treatments. Average marketable yield for all cultivars with sprinkle irrigation (47.4 t/ha) outyielded drip irrigation (38.2 t/ha) by 24% and nonirrigation (21.3 t/ha) by 123%.

GREENHOUSE VEGETABLES

Cucumbers

Biological control of cucumber powdery mildew. Yeast-like *Sporothrix* spp. have been evaluated for their ability to biologically control powdery mildew caused by *Sphaerotheca fuliginea* (Schlect.: Fr.)Pollacci in the greenhouse under commercial production conditions. The *Sporothrix* antagonists were more effective in retarding powdery mildew development when applied at the time of seedling emergence and when the relative humidity was controlled at 80%.

Tomatoes

Biological control of fusarium rot. Antagonistic filamentous bacteria (*Streptomyces* spp.) were shown to reduce significantly fusarium crown and root rot (*Fusarium oxysporum* f. sp. *radicis-lycopersici* Jarvis & Shoem.) when applied shortly after sterilization of greenhouse soil. Allelopathic biological control, with companion planting or the application of chopped lettuce to greenhouse soils, was shown to reduce the infection of tomato roots by depriving the pathogen of iron necessary for growth.

Stem necrosis. A new disease of greenhouse tomato, bacterial stem necrosis, was caused by *Pseudomonas* sp. The disease symptoms differed from those of bacterial stem rot caused by *Erwinia carotovora* ssp. *carotovora*. Discontinuous necrosis of nodal tissue occurred earlier, followed by extension to internodes and leaf rachii and extensive browning of the pith. The plants did not lose their turgor, unlike in the erwinia stem rot. Although the causal bacteria were similar to *P. cichorii* (a broad host-range pathogen) in being oxidase-positive and arginine-dihydrolase-negative, they differed in many other key physiological characteristics and pathogenicity, enough to be considered a new taxonomic category.

The Harrow Fertigation Manager (patent pending). In highly intensive agricultural systems (e.g. greenhouse crop production), fertilizer application requires continuous attention and adjustment to ensure adequate nutrient supply. The newly developed Harrow Fertigation Manager (HFM) addresses this practical problem and makes it possible to meet the diverse nutrient requirements of a number of crops from one set of fertilizer stock solutions. The HFM uses a microcomputer to activate a series of dosimetric pumps for the programmed application of desired concentrations of individual nutrients. In addition, the HFM automatically adjusts the supply of water and individual nutrients to the crops according to stored information and crop and environment status as monitored by sensors. The system can operate either manually or automatically, is equipped with self-checking software and alarms, and its software is universal enough to control a great variety of electric, hydraulic, or air-driven fertilizer pumps. Besides its practical application in the commercial production of crops, the HFM can be a powerful tool in plant nutrition research.

TREE FRUITS

Apple

Control of the codling moth by granulosis virus. Orchard tests carried out in cooperation with the University of Guelph and with other institutions in Canada in the past several years have demonstrated that the granulosis virus is effective in the management of the codling moth on apples and that the virus has a minimum effect on nontarget arthropods in the orchard. In the 1988 orchard test at Guelph, codling moth larvae caused deep-entry damage in 3.0% of apples sprayed with the virus and in 19.2% of apples in nonsprayed plots. In the 1986 test none of the apples in virus-treated plots were damaged by the insect, whereas 10.1% of nonsprayed apples were damaged. The granulosis virus is particularly attractive as an alternative to broad-spectrum chemical insecticides in integrated pest management systems for apple because the virus has a minimum effect on parasitic and predaceous species that regulate other pests such as the European red mite.

Apricot

Breeding. Six selections (HW450, HW451, HW452, HW453, HW454, HW455) from 1982 crosses with ripeness dates from 15 July to 30 July were advanced for placement in regional trials in 1989 in cooperation with the Western Ontario Fruit Testing Association (WOFTA). These selections are suitable for testing in southern Ontario and southern British Columbia because they appear to have adequate coldhardiness, disease resistance, and productivity combined with sufficient fruit size, color, and quality to satisfy fresh-market requirements.

Controlled freezing tests of fully acclimated, detached, dormant shoots were carried out, and the temperatures required to kill 50% of the flower buds and 50% of the shoot xylem were determined. The cultivars Harlayne and Harglow and the line HW440 exceeded the hardiness of Goldcot, the hardy standard. Cultivars or advanced selections that exceeded the shoot xylem hardiness of Goldcot included HW436, HW439, and HW440. Of twelve Harrow seedling selections compared with Goldcot for hardiness, three were significantly more bud-hardy (H8205025, H8208004, H8208273) and two were significantly more wood-hardy (H8202030, H8205025). The

remainder were similar in hardiness to Goldcot. The technique showed that it is possible to select apricots with improved coldhardiness.

Nectarine

Breeding. The best Harrow selections were crossed with two of the best California cultivars, Fantasia and Stark's Redgold. Four very promising selections (H7936029, HW104, HW106, H7938023) ripening from 4 August to 1 September appear worthy of testing in southern Ontario and southern British Columbia and could provide a 4- to 5-week supply of attractive, high-quality nectarines for the fresh market.

Peach

Biological control of cylindrocarpon root rot. The incidence and severity of peach root rot caused by the fungus *Cylindrocarpon destructans* (Zinss.) Scholten were reduced significantly by prior colonization with the vesicular-arbuscular mycorrhizal fungus *Glomus aggregatum* Schenck & Smith under greenhouse conditions. This symbiotic fungus isolated from local peach soils acted as a biological agent for cylindrocarpon root rot, which was shown to be a major component of replant and establishment problems in peach orchards.

Biological control of perennial canker. Regular sampling of healthy and cankered bark from scaffold branches of peach trees during fall, winter, and spring has revealed that *Leucostoma persoonii* (Nits.) Höhn. is predominant over *L. cincta* (Fr.) Höhn. as a canker-causing agent. Significantly different communities of fungal epiphytes were found on the bark of healthy versus cankered trees. Yeasts and filamentous fungi with dark-colored walls were always associated with the canker-causing *Leucostoma* spp. Artificial inoculation of wounded bark on potted trees has revealed that *Aureobasidium pullulans* (de Bary) Arn. and *Epicoccum purpurascens* Ehr.: Schlecht. are effective biological control epiphytes if applied before or at the same time as *L. persoonii*.

Breeding. Sixteen cultivars and advanced selections were tested by controlled freezing of detached, dormant, maximally acclimated shoots. The temperatures required to kill 50% of the flower buds and 50% of the shoot xylem were determined and compared with Redhaven, the hardy commercial standard. Six were significantly more hardy than Redhaven and six were as hardy as Redhaven. Two entries were more wood-hardy than Redhaven, five were equally wood-hardy, and six were less hardy than Redhaven. In general, a close correlation of the rank order of bud and wood hardiness was found among the 16 entries tested.

Integrated orchard management. Three cultivars, two ground covers, and two irrigation treatments were tested in a Fox sand orchard. There were cultivar effects in bud hardiness, wood hardiness, and yield; an irrigation effect on wood hardiness; and a cultivar-ground cover interaction for trunk cross section.

Rootstocks. Ten peach seedling rootstocks having Redhaven as the common scion tester have been under evaluation since 1982 on a Fox sand. In 1988, a hot, dry growing season, the rootstocks differed significantly in their effect on scion hardiness of flower buds, winter kill ratings, tree vigor, bloom intensity, fruit set, total yield, marketable yield, split pits, and cropping efficiency. The rank order in general rootstock performance from best to worst was as follows: H7338019, Chui Lum Tao, H7338013, H7338016, Tzim Pee Tao, Lovell, Halford, Siberian C, Bailey, and Harrow Blood. Chui Lum Tao, a hardy Chinese introduction, and the three Harrow selections were better rootstocks for peach than were the commercial standards, Halford, Lovell, Bailey, and Siberian C. They show promise as future commercial rootstocks for peach.

Screening for canker resistance. An artificial screening test based on the necrotic response of peach bark and leaf tissues to oxalic acid has revealed significant differences among peach cultivars. These results indicate a role for oxalic acid, a toxic metabolite produced by *Leucostoma* spp., in detecting canker resistance.

Pear

Breeding. Three seedlings with good fresh-fruit quality were selected in 1988. They have fire blight [*Erwinia amylovora* (Burrill Winslow et al.] resistance similar to Kieffer, and their fruit had good ratings for appearance, flavor, texture, freedom from grit, and fruit size.

A breeding program was initiated to incorporate pear psylla (*Psylla pyricola* Foerster) resistance into high-quality, fire-blight-resistant pears. The source of resistance is *Pyrus ussuriensis*. Pollen from *P. ussuriensis* × *P. communis* selections resistant to pear psylla was used for crossing with Bartlett, Harvest Queen, Harrow Delight, and HW609. A total of 1600 controlled hybridizations yielded 650 seeds.

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Experimental Farm
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INTRODUCTION

The Kapuskasing Experimental Farm was established in 1914 to support agricultural development of the Great Clay Belt of northeastern Ontario and northwestern Quebec. The farm maintains a beef herd of 200 animal units on 450 ha. An experimental site is maintained on leased land in northwestern Quebec. Research projects in cereal and forage production at that site are supervised by two professionals occupying rented office space in Rouyn-Noranda. The Kapuskasing Experimental Farm is also accountable for the Thunder Bay Experimental Farm, which has a surface area of 25 ha.

The main mandate of Kapuskasing is to conduct beef cattle research for northern Ontario and Quebec. To that end, we are collaborating with Laval University and the University of Guelph, as well as with scientists from the Animal Research Centre and the Lennoxville Research Station. Forage crop research, including pasture and stored feed, is being integrated into the beef cattle research programs. Cultural practices for short-season growing areas have been determined, and resources are being shifted toward forage and beef research. Small projects in support of the development of the area's peat and phosphate resources are important for sustainable agriculture.

The Kapuskasing Experimental Farm supports the forage and cereal provincial crop committees of both Ontario and Quebec. Research projects are conducted in collaboration with the following federal research establishments: Sainte-Foy Research Station; Lennoxville Research Station; and, in Ottawa, Plant Research Centre, Animal Research Centre, Land Resource Research Centre, and Engineering and Statistical Research Centre. Certain projects are also conducted in collaboration with scientists from the University of Guelph, Laval University, and Macdonald College. A memorandum of understanding is currently being developed with the Ontario Ministry of Agriculture and Food's College of Agricultural Technology at New Liskeard.

The Kapuskasing Experimental Farm and the Thunder Bay Experimental Farm operate with 32 person-years, including four professional positions. The nonpay operating budget of both farms is $345 000. A major capital project of $300 000 was completed in 1988. Minor construction and equipment expenditures consisted of $125 000 and $130 000, respectively.

Further enquiries can be directed to the Kapuskasing Experimental Farm, Research Branch, Agriculture Canada, Kapuskasing, Ont. P5N 2X9; Tel: (705) 335-6148.

J.G. Proulx
Superintendent

ANIMAL PRODUCTION

Beef cattle management

Cow–calf production. Five feeding trials performed on ranches in western Canada and northwestern Ontario confirmed that a distinctive, recurring congenital anomaly in beef calves was associated with feeding pregnant cows with clover or grass silage exclusively over the winter. The anomaly, termed congenital joint laxity and dwarfism, was characterized at birth by generalized joint laxity, disproportionate dwarfism, and occasionally superior brachygnathia. Pregnant cows were divided randomly into feeding groups, and the number of abnormal calves in each group was tabulated. The condition occurred on both red clover and grass silages. Supplementation of these diets with hay (2.5–4.5 kg per head per day) and rolled barley (0.75–1.5 kg per head per day) eliminated the problem. Supplementation of grain without hay was not as effective. Varying the proportion of grass and clover in the silage or the age of the silage did not alter the teratogenetic potency of the silage. Vitamin D_3 supplementation did not reduce the risk of the condition. A trial conducted at the Kapuskasing Experimental Farm demonstrated that copper supplementation of grass silage did not alter the incidence of the condition. The incidence was observed to be much higher in calves born to 2-year-old heifers than to adult cows.

Reproduction. Conventional estrus synchronization was compared with timed insemination at 48 and 72 h after removal of a protestagen (Synchromate-B); 100 and 94 cows were randomly assigned to each group.

Conception rate after a 35-day breeding season was similar for both groups. Services required per conception were, respectively, 1.61 and 3.17. Cost of the protestagen, higher expenditures for semen, and the increased handling of the cows by using the Synchromate-B product make this breeding system economically unattractive for the commercial beef producer.

Beef cattle nutrition. Projects conducted in beef cattle nutrition are to be found in the report of the Animal Research Centre.

CROP PRODUCTION

Cereal evaluation

Six-row barley cultivars compared with two-row cultivars. Twenty-two official entries were evaluated at Kapuskasing in the 1988 Ontario regional barley trial. Ten entries were two-row cultivars, 12 were six-row entries, and two additional entries were added to our trial for their earliness. The six-row entries yielded 391 kg/ha more grain than the two-row entries, which is usually the case in most years. The six-row entries also ripened about 1 day earlier than the two-row entries. However, the lodging resistance of the six-row type was 2.5, whereas that of the two-row type was only 1.9. The two early-maturing entries, Nord and Otal, yielded 308 kg/ha less than the two-row cultivars. However, they ripened 7–8 days earlier. The lodging resistance of the early-maturing entries was 3.8 compared with 2.5 and 1.9 for the six-row and two-row entries.

The top-yielding barley cultivars from the Ontario regional barley trials at Thunder Bay were Rodeo at 3439 kg/ha and TBE 611 20 at 2413 kg/ha. The mean for the trial was 2053 kg/ha. The top-yielding oat cultivars from the Ontario regional oat trials were Oxford at 3099 kg/ha and OAC Woodstock at 3063 kg/ha. The mean for the trial was 2743 kg/ha.

Cereal management

Barley blends. Leger, Sophie, Bruce, and Mingo six-row barley were compared at Kapuskasing, with Herta and Birka two-row barley sown in monoculture or in blends. Three years of data have revealed that Leger continues to be the highest grain-yielding cultivar when sown alone or in blends. The five highest grain-yielding cultivars or blends all had Leger in the 3 years of testing. The second group of blends that performed best contained the cultivar Sophie, followed by a group of blends that contained Herta. At the bottom of the yield production table stood the entry Birka, along with the blends containing Birka. On the average, cultivars sown in blends had less lodging than a seeding in monoculture.

Forage evaluation

Forage cultivar trials. Three alfalfa trials were run at Thunder Bay. Top yielding cultivars were A872 at 5931 kg/ha and NAPB 31 at 5784 kg/ha. Magnum, the top-yielding cultivar in 1987, with a yield of 6094 kg/ha, had a yield of 4519 kg/ha in 1988; OAC Minto, which had the second highest yield in 1987, with 5007 kg/ha, yielded 4691 kg/ha in 1988.

Four grass trials were run at Thunder Bay. Dan (M3-8569) had the highest yield for the third straight year in meadow foxtail at 4162 kg/ha compared with 4327 kg/ha in 1987 and 4561 kg/ha in 1986. Kay was the highest yielding orchardgrass at 4878 kg/ha, followed by 14-78-3 at 4714 kg/ha. The highest yielding orchardgrass from 1987, SF 8501 at 5655 kg/ha, yielded 4656 kg/ha in 1988. The top yields in bromegrass were Blair at 7523 kg/ha and Beacon at 7350 kg/ha. The top yields in tall fescue were Syn A at 5822 kg/ha and Stef at 5794 kg/ha.

Forage management

Water-soluble carbohydrates. The level of water-soluble carbohydrates (WSC) is an important quality parameter in forages for ensuring fermentation of crops as silage. WSC levels of 12–13% of dry matter are considered critical for humid crops (20–25% dry matter). A survey of grasses harvested during the first vegetation cycle in 1987 in the Great Clay Belt region on commercial farms showed that WSC were in the range of 14–17%, depending on the species. WSC were lowest for quackgrass and orchardgrass, averaging 14 and 15%, respectively, and highest for grassland, averaging 17.5% (no species represent more than 50% of the stand). Data also showed that WSC were variable within species, varying from 10 to 24%. WSC decreased as the plant matured. They were highest at jointing and boot stages, averaging 16.9%, and lowest at heading stage, with 14.7%. There was a difference of 2.5% in WSC between morning and afternoon samplings. Nitrogen fertilization decreased WSC but not as much as expected. There is a difference of about 1% in WSC with and

without nitrogen, but appreciable differences between levels of nitrogen (1–90 kg/ha) were not evident. Results of the survey showed that WSC were generally high enough to ensure good fermentation of silage in grass crops.

Performance of perennial ryegrass

Six medium-maturing perennial ryegrass cultivars were compared with Hallmark orchardgrass sown in monoculture or in mixtures with Ladino white clover in 1987. Hallmark orchardgrass had a 4.2% winterkill, whereas the ryegrass ranged from 16.7% for Bastion to 92.5% for Bison. Seeding ryegrass with Ladino did not significantly change the percentage of winterkill. On average, the medium types of ryegrass had a 19.2% winterkill over the first winter. Seasonal dry-matter yields were increased from 3253 kg/ha when sown in pure stands to 4483 kg/ha when sown with Ladino white clover. In a pure stand Hallmark yielded at least twice as much as the best yielding ryegrass, whereas in a mixture with Ladino the orchardgrass was only slightly better than the best ryegrass mixture.

Another similar trial compared nine cultivars of late-maturing perennial ryegrass with Kay orchardgrass sown in monoculture or in a mixture with Ladino white clover. The winterkill damage was higher in the late-maturing types, with 80% losses over the first winter. The check Kay orchardgrass had an average of 7% loss, whereas the late ryegrasses ranged from 38% for WWE-37 to 98% for Gladiator. Seeding the ryegrasses with Ladino white clover reduced the winterkill damage from 80 to 64%. As in the case of the medium types, the addition of Ladino white clover to ryegrass increased total seasonal dry-matter products from 1752 kg/ha to 4685 kg/ha. In a pure stand Kay orchardgrass significantly outyielded any of the late-type perennial ryegrasses. The addition of Ladino white clover did not significantly increase the seasonal dry-matter yield of Kay orchardgrass.

Potato breeding

Cultivar evaluation. Unusually warm and dry conditions for the early part of May in Thunder Bay allowed the completion of planting for multiplication stock by 20 May 1988. This program contains 22 cultivars and eight breeders' lines for multiplication for Ontario regional potato trials. Approximately 4 t of potatoes were shipped to Guelph for distribution to the six cooperators.

Selections were made from 42 breeders' lines that will be entered in the 1989 single-hill trials; 142 selections from single hills will proceed to 10-hill trials and 24 10-hill trials will progress to the 1989 100-hill trials.

Thirteen breeders' lines were bulked up for entry into the Ontario regional potato trials in 1990. Two of these are G8525OP, a white-fleshed, purple-skinned cultivar; and FTB 871-1, a white-fleshed, red- and white-skinned bicolor similar to the British cultivar King Edward. Both cultivars produced good, consistent yields under adverse conditions in 1988. These two cultivars have been sent to Agriculture Canada's laboratory in Vancouver for virus freeing.

Of 16 cultivars sent to Florida for virus testing (100 tubers of each), only one tuber of the cultivar Onaway showed any symptoms of mosaic.

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Research

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A.D. Tomlin, B.A., M.Sc., Ph.D.	Pesticide ecology
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Departures

W. Chefurka,[4] B.Sc., M.Sc., Ph.D. Retired 5 April 1988	Insect biochemistry
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R.C. Zimmer, B.Sc., Ph.D. Transfer of work from Morden Research Station	Plant diseases

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[4] Part-time work for Retired Research Scientists Program.

INTRODUCTION

The London Research Centre was established in 1951 to investigate the ecological effects of the use of agricultural chemicals (other than fertilizers) with the purpose of ensuring that the widespread or continued use of pesticides does not have harmful consequences on soil fertility, beneficial organisms, and crop quality.

During 1988 the new, long-awaited laboratory–office complex to house the Soil Pesticides Section was completed. The move from the downtown rented space took place in October. The disruption of the research of this section necessitated by the move was mitigated by the new, extensive insect-rearing facilities, possibly the finest in North America, which will provide the means to mass-produce biological control agents, thereby enhancing program initiatives in this area. Present research programs continue to reflect environmental and health concerns regarding the agricultural use of pesticides. The original mandate has been extended to examine alternative pest control procedures to replace or severely curtail current pesticide use. The aim is to develop new procedures for environmentally acceptable pest control, with the primary focus on the utilization of natural defense mechanisms of crops against plant pathogens, and insect pests and biological control agents against insect pests.

To meet the above objectives, multidisciplinary teams carry out research primarily in four areas, with the following goals: to provide leads that could be used in a unique manner for the selective disruption of communication, growth, development, or reproduction of the pest in an environmentally acceptable manner; to investigate the detailed biology and ecology of selected native potential biological control agents and to develop improved methodology for mass culture, introduction, and maintenance of these indigenous control agents in conjunction with other environmentally acceptable procedures; to utilize natural defence and resistance mechanisms in crops by developing a detailed understanding of host–pest interactions at the biochemical, physiological, and cellular levels; and to develop new and improved knowledge of the nature, behavior, movement, and fate of soil pesticides in relation to their impact on nontarget organisms, vital soil processes, and factors that influence their performance, toxicology, and environmental safety in crops, soils, and water.

The main laboratory is on the campus of the University of Western Ontario. Its primary emphasis is on plant pathology, and it is also the centre of administration. The new Packs Lane laboratory is some 10 min away. It is adjacent to the 25-ha research farm that is maintained virtually pesticide-free so that environmental studies can be more easily pursued. The London Research Centre has 69 person-years, including 22 professionals, and an operating budget of $450 000.

This report records only the highlights of our accomplishments for 1988; more detailed information can be obtained from the publication titles listed at the end of the report. Copies of the report, reprints of publications, and further information are available on request from the Research Centre, Agriculture Canada, 1400 Western Road, London, Ont. N6G 2V4; Tel. (519) 645-4452.

H.V. Morley
Director

ENVIRONMENTAL STUDIES

Research in this area falls under two broad categories. The first is concerned with the impact or potential impact of present pesticide use on the environment. The second is primarily concerned with research that will avoid or drastically reduce the release, into the environment, of broad-spectrum toxicants used for pest control.

Pesticide impact on nontarget organisms

Studies over the past 4 years have shown that soil microorganisms can develop the ability to rapidly degrade nearly all soil-applied insecticides or their insecticidal transformation products. Under optimum environmental conditions anti-insecticide activity is generated within 6 weeks of the first treatment. Anti-insecticide activity has not occurred with tefluthrin or chlorpyrifos. Tests

have indicated that the hydrolysis product of chlorpyrifos (3,5,6-trichloro-2-pyridinol, or TCP) has antimicrobial properties, suggesting that as TCP is generated in soil, it provides a degree of "protection" of the parent material. Some indirect support for this theory was obtained in laboratory studies: in soils known to possess a high level of anti-insecticide activity, carbofuran, isofenphos, and Dowco 429X were all more persistent when the soil was pretreated with TCP.

Enhanced microbial degradation results in erratic pest control that may be erroneously attributed to resistance, leading to increased applications of soil pesticides. A better understanding of the processes may allow the use of inhibitors in formulations or the utilization of a process to remove undesirable residues from the environment.

Heating clay-loam soils at 45°C for 4 weeks was found to destroy anticarbofuran, anti-isofenphos, antialdicarb sulfoxide, and anti-Dowco 429X activity initially present. A field study was carried out on the effect of solarization under plastic on the persistence of carbofuran in soil and the development of anticarbofuran activity. The disappearance rate was significantly reduced in plots solarized immediately after treatment, and anticarbofuran activity did not develop in these plots over 7 weeks. Plots not solarized immediately developed anticarbofuran activity within 2 weeks. Solarization of these plots 3 weeks after treatment caused a detectable decrease in anticarbofuran activity at 5 weeks and a significant decrease at 7 weeks.

Resistance

The development of resistance by the pest is a nondesired impact of the pesticide on target organisms leading to a breakdown in control and increased input of pesticides to the environment in an effort to maintain control of the pest. It is also possible that in the absence of "hard" data, the occurrence of enhanced microbial degradation might be ascribed to resistance.

Colorado potato beetle (CPB), *Leptinotarsa decemlineata* (Say), from seven potato-growing areas across Ontario was monitored for resistance to representative insecticides. High resistance to carbofuran was identified in six of seven populations; endosulfan resistance was >30-fold in four of six collections. Resistance to deltamethrin and fenvalerate varied, reaching a high of 30-fold in one collection. All populations showed moderate resistance to azinphos-methyl but remained susceptible to aldicarb. In laboratory tests, abamectin, cyhalothrin, and cyfluthrin were highly toxic to insecticide-susceptible CPB; the two pyrethroids were approximately one-tenth as toxic to a resistant strain. In field microplot tests, foliar applications of RH-5849 and cyhalothrin provided excellent control of insecticide-susceptible CPB. *Bacillus thuringiensis* var. *san diego* and *B. thuringiensis* var. *tenebrionis* gave fair to good control of small larvae early in the season.

Another potential consequence is the effect of pesticides on the life functions of beneficial soil organisms, which could affect soil enzyme activities and microbial respiration. The effects of four soil insecticides, Dowco 429X, chlorethoxyphos, tefluthrin, and trimethacarb on microbial activities in a sandy loam soil and an organic soil were evaluated. Results showed that although some short-term effects on numbers and activities were observed, they were not drastic enough or prolonged enough to be considered deleterious to soil organisms examined or to their activities in relation to soil fertility.

Pesticide movement and persistence

The probability of ground-water contamination from agricultural pesticides is determined by the relative rates of percolation through, and degradation within, the soil profile. The use of field lysimeters enables an investigation of the relative mobility and persistence of commercial formulations. The end objective is to predict accurately the potential of the pesticide to leach to ground water. Field lysimeters packed with Plainfield sand were used to study the persistence and mobility of commercial formulations of the herbicides atrazine, metolachlor, and terbuthylazine. The choice of soil type was an attempt to simulate the most probable conditions for ground-water contamination. Based on effluent and soil core data, the three herbicides exhibited limited movement under moderate rainfall patterns. Two of the three applied herbicides appeared to be more susceptible to rapid leaching for a 24-h period following application. This in turn suggests that soil-water partitioning coefficients obtained by traditional laboratory stirring methods may not accurately reflect the restricted soil–pesticide contact available in the field in normally unsaturated soils.

ALTERNATIVE PEST CONTROL STRATEGIES

Biological control

Entomogenous fungi have long been known to play an important role in the natural regulation of many insect pests. Few examples of successful control are available, however, primarily because of the lack of knowledge of the interaction between host and pathogen. To study this interaction, isolation and growth of the entomogenous fungus in pure culture on artificial media are necessary. An efficient technique has now been developed for the isolation, in vitro growth, and laboratory production of *Entomophthora muscae* (Cohn). The fungal isolates have now been through 3 years of continuous subculture without reversion to hyphal form, conidia or resting spore formation, or loss of infectivity. Examination by scanning electron microscopy has demonstrated that the attachment of conidia to insect host epicuticle is mediated by the hydrophobic nature of the conidial wall and the epicuticle of the host.

Continuing research on potential insect biological control agents was severely curtailed because of the need to move the insect-rearing facilities to the new building.

The second year of an experiment to test the feasibility of using *Aleochara bilineata* (Ab) to control root maggots in home gardens met with considerable success. In both years significant reductions in infestations of cabbage maggot in radishes were related to the release of Ab. In 1988 three different levels of Ab release were used and demonstrated that the percentage of damage was inversely related to the number of Ab released. The results with onion maggots in both onion sets and bunching onions from seed were inconclusive. Apparently Ab is a more effective parasitoid of the cabbage maggot than the onion maggot. This agrees in large measure with the results from Europe.

Plant diseases

Research in this area is directed toward obtaining an appreciation of the basic processes involved in plant-pathogen interactions in resistant and susceptible crops. The potential benefits of these studies would be the ability to activate the plants' natural defense mechanisms and to provide a firm basis for breeding for genetic resistance.

Cytological studies of the early stages of infection of soybeans by the pathogen *Phytophthora megasperma* f. sp. *glycinea* yielded several important findings. Invasion of soybean plants was shown to occur very rapidly; 2 h after inoculation, hyphae have reached the cortex. Resistant and susceptible responses can be distinguished at this time, and differences become more pronounced 3, 5, and 7 h after inoculation. In resistant responses cells die immediately, and in susceptible responses cells remain intact. Thus, there is clearly almost immediate recognition of the pathogen in the resistant responses and an absence of recognition in the susceptible responses where a biotrophic phase is established at least temporarily. The study provides a time course with which the genetic and biochemical responses of the plant to infection can be correlated.

A highly sensitive enzyme-linked immunosorbent assay (ELISA) procedure has been developed for the determination of abscisic acid levels in infected plants, which will enable investigation of the role this hormone plays in the plant's response to infection. There has been speculation and conflicting evidence for many years that hormones are involved in regulating disease defence responses. Measurement of hormones has been previously dependent on bioassays or on the extraction of large amounts of tissues. The ELISA procedure allows the measurement of concentrations within single lesions rather than gross changes within tissues, only a small part of which may be involved in the disease reaction. Results so far indicate that there are distinct changes in abscisic acid levels during infection, with timing differences in resistant and susceptible responses. This finding suggests that abscisic acid exercises control over defence responses.

Work was continued on phytotoxic secondary metabolites of fungi and bacteria that are known in some cases to be causal factors in plant diseases. A collaborative study with workers at Harrow Research Station, on a fungus isolated as a cucumber-infecting pathogen from a greenhouse, has demonstrated the utility of chemical studies for the correct identification of species as well as for the assessment of toxicological hazards. A postulated key intermediate on the biosynthetic pathway to the molluscicidal fungal metabolite traversianal has been isolated and identified from cultures of the fungus. Testing by an outside laboratory has revealed that

traversianal also has antileukemic activity. A biosynthetic study has confirmed that the mycotoxins orlandin and kotanin are rare examples of structures that are in conflict with a generally accepted biogenetic rule; this might provide leads to specific control measures.

The possibility that the inhibition of the fungal toxin altersolanol was caused by the accumulation of toxic levels of melanin precursors, rather than tricyclazole itself, was investigated using a fungus that does not produce melanin but does produce several pentaketide-derived phytotoxins. The organism selected was the soil borne pathogen of onion, *Pyrenochaeta terrestris* (Hansen) Gorenz, Walker & Larson. Tricyclazole was demonstrated conclusively to inhibit the biosynthesis of a wide range of pentaketide-derived fungal products including secalonic acid, a product of numerous fungi that is regarded as a mycotoxin dangerous to human and animal health. The other product found to be inhibited by tricyclazole was the pigment cynodontin. Treated cultures accumulated numerous pigments that were not found in control cultures. Many of these products have been purified, chemically characterized, and identified and have confirmed the theoretical biosynthetic pathways proposed in the literature. These findings can be considered to be of some significance, in light of the wide range of other mycotoxins synthesized by the same biochemical pathway.

Studies on the mode of action of the phytotoxin helminthosporal and the insect antifeedant polygodial revealed that they both interact with the electron transfer respiratory chain and prevent pyridine nucleotide (NADH) and succinate-linked reduction of coenzyme Q10 and cytochrome *b*, and can inhibit reversed electron flow from cytochrome *c* to nicotine–adenine dinucleotide (NADH). It appears that these compounds can react with protein amino groups involved in the function of the electron flow chain.

A 30-kilobase (kb) segment of *Pseudomonas syringae* pv. *tomato* DNA required for production of the phytotoxin coronatine has been cloned. The clone restored toxin production to four of five toxin-negative mutants. Restriction enzyme analysis and subcloning indicated that almost the entire 30 kb were required for toxin production. A 5.3-kb internal fragment of this clone was labeled nonradioactively and was used as a probe to screen other *P. syringae* pathovars, other bacterial tomato pathogens, and tomato plant epiphytes for the presence of coronatine genes. Only the coronatine-producing *P. syringae* pathovars, pv. *tomato*, pv. *glycinea* (soybean pathogen), pv. *maculicola* (crucifer pathogen), and pv. *atropurpurea* (Italian ryegrass pathogen), reacted with the probe. Thus, the genes present on this clone are highly conserved and exclusive to those *P. syringae* pathovars that produce coronatine. The nonradioactively-labeled DNA probe has the potential to serve as a safe and effective means of identifying the bacterial speck pathogen and the soybean bacterial blight pathogen in field, seed, and plant samples. Alternatively, one of the protein products of this DNA could serve as an antigen in the development of a serologically based diagnostic kit for the two diseases. Either approach should help in the phytosanitary certification of tomato and soybean seed destined for export.

A tomato tissue-culture bioassay has been developed. The assay distinguishes extracts from pathogenic *Fusarium* cultures and those from nonpathogenic fusaria. The disease system being examined is the economically important wilt disease in tomato crops located primarily in southern Ontario.

Single-cell tomato tissue culture was used to facilitate and obtain uniform effects on all cells in the system with the treatment extracts from the various isolates of the pathogens. This uniformity could not be obtained with callus tissues. In order to amplify the small differences in respiration and [^{14}C]methionine uptake that were obtained, the tomato cells were pretreated with metabolic modifiers. With indoleacetic acid pretreatment, the differences in methionine uptake were dramatic and significant between the cultures treated with "pathogen extracts" and the control cultures. This study is being done cooperatively with Dr. W. Jarvis, Harrow Research Station.

Solarization

Solarization has been shown in other countries to be a promising technique for control of soil-borne diseases, eliminating the need for soil fumigation. Coverage of vast areas may not be practical, but for home garden use, for low-hectarage high-value cash crops, and for greenhouse soils there is an immediate potential use.

Collaborative studies were continued in south-central Ontario on the effect of solarization (heating soils under transparent plastic) on populations of the soil-borne fungal pathogen *Verticillium dahliae*, on several species of plant parasitic nematodes, and on the subsequent health and productivity of potatoes. Soil temperatures were monitored at various depths at 15 min intervals over 8 weeks in two of the six tarped and control plots. Sampling for nematodes and *V. dahliae* was performed before and after tarping and before and after planting in the subsequent year. In addition, *V. dahliae* microsclerotia were buried at various depths before solarization to assess their survival. Laboratory experiments determined the effect of specific temperatures on the mortality of these resting structures. Chemical analyses of the organic and inorganic constituents of the soils were conducted before and after treatment.

Temperatures in solarized soils on the average were 7–10°C higher than in soils at comparable depths in nonsolarized plots. This difference was evident within 24 h after tarping and remained uniform during the solarization period. Temperatures in the top 10 cm exceeded 40°C for an average of 8–9 h/day, which in laboratory experiments reduced microsclerotia viability by at least 90%. Maximum temperatures of about 50°C were recorded in the top 10 cm of tarped plots. Both nematode and *V. dahliae* populations were eliminated or significantly reduced in the top 15 cm of soil but not at the lower depths. Incidence of verticillium wilt was reduced in solarized plots by 10 August from 30, 35, and 15% to 5, 15, and 0% in Kennebec, Norchip, and A66107-51 (a *Verticillium*-resistant cultivar), respectively. Yield increases as a result of solarization for these three cultivars were 25, 43, and 19%, of which only the increase for Norchip was statistically significant. Total nitrogen levels increased up to 300% in the top 10 cm of solarized soils and up to 50% in the next 10 cm. No increase was observed at the lower depths.

Mode of action

A large variety of new furan carboxamides, substituted 2-methylbenzanilides, and oxathiin carboxamides were synthesized and found to be potent inhibitors of the succinate dehydrogenase complex (SDC) in wild-type and carboxin-resistant strains of *Ustilago maydis* (DC.) Corda (corn smut). Of importance was that a wide variety of 4'-substituent groups on the parent anilides produced compounds more inhibitory to the mutant SDC than toward the wild-type enzyme complex. Such compounds may be of importance in controlling naturally occurring carboxin-resistant fungi.

Further research was carried out on the role of indole-3-acetic acid (IAA) in the chemical regulation of plant growth and in pesticide–plant interactions. An analytical procedure was developed to isolate an unstable major metabolite resulting from the effect of the herbicide glyphosate on IAA metabolism in soybeans. Using a combination of normal and reverse phase HPLC and radioassay for isolation, this major metabolite has been tentatively identified as being a conjugate of indole-3-methanol.

STORED PRODUCTS

The mode of toxic action of the fumigant phosphine (PH_3) has remained a mystery for over 50 years during which time it has been used as an insecticide in stored products in many areas of the world. It is known that PH_3 inhibits cytochrome c oxidase of the respiratory chain. However, this does not appear to be the major cause of insect death. Investigations carried out over the past 4 years suggest that PH_3 toxicity may be related to the production of superoxide radicals from the inhibited respiratory chain. Oxygen-derived radicals are highly cytoxic and can oxidize most cellular components including lipids, proteins, and nucleic acids. A gradual accumulation of cellular damage could explain why insects take several days to die after fumigation.

In vitro studies revealed that insect mitochondria challenged with PH_3 release H_2O_2, a measure of superoxide radical generation. Insects exposed to PH_3 showed increased superoxide dismutase activity, and since this enzyme removes superoxide radicals, this finding reaffirms that fumigated insects may produce them in vivo.

These findings have implications for the application of PH_3, because superoxide radical generation is increased at higher oxygen concentrations. By lowering the oxygen concentration before fumigation, the activity of antioxidant enzymes should be decreased, making the insects sensitive to less PH_3, especially if it is accompanied by higher oxygen concentrations.

Additional information required by regulatory authorities has been obtained concerning the identity of chemically bound residues formed during fumigation with [^{14}C]methyl bromide. Studies of the sites of protein methylation have now been extended to include 10 commodities. Methylation of methionine accounts for only 6% of the chemically bound residue in alfalfa but for 28–30% in apples, potatoes, and wheat. Histidine also accounted for a major portion of the residue. Among the hydrolysis products that have been identified are 1- and 3-methylhistidine. In corn and almonds the bound residues associated with both the protein and the DNA were stable over a 6-month period.

A cooperative project with the Food Production and Inspection Branch was initiated to determine the conditions under which phosphine can be safely used to control effectively all stages of the Hessian fly in compressed and chopped hay. The data are needed to satisfy requirements of Japanese authorities regarding the import of hay. The most critical factor for the initiation of the project was the successful rearing of large numbers of the Canadian strain of the Hessian fly on a year-round basis. This task was finally accomplished with the move to the new mass-rearing facility at the end of the year. Mass rearing of this insect has now been achieved for the first time in Canada. Insects are also being provided to the University of Saskatchewan for thermal studies on the insect. Studies on phosphine penetration, sorption, and desorption using bales of compressed hay have been completed, and residue levels resulting from phosphine treatment of loose hay have been established and should present no problems to regulatory authorities.

Previous work in this laboratory resulted in the isolation of a unique insect protein kinase involved in the insect molt. Research was started on the enzyme trehalose to establish its nature and to determine if its activity is controlled by the molt protein kinase. Because trehalose is found only in insects, its control by the protein kinase would provide a logical focal point for a rational approach to biological control. Two forms of trehalase enzyme have been identified and separated from grasshoppers, crickets, and flies.

With the use of the model system developed here, the impact of various insecticides and fungicides on membrane transport processes in living cells was investigated. Many organochlorine and pyrethroid fungicides as well as the fungicides dodine, captan, phaltan, difolatan, and thiophanate have been shown to interfere directly with metabolite transport across the cell membrane. Fungicides active in the model system were also shown to block transport in the smut fungus. The possibility that this general inhibitory effect on transport by some pesticides may provide a predictive capability for determining potential impact on nontarget organisms is being investigated.

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Departure

N.J. Smits, B.Sc. Retired 28 September 1988	Vegetable management

EXTENSION SERVICES[3]

D. Ridgway	Fruit and vegetable crops

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[1] Seconded from Libraries Division, Corporate Management Branch.
[2] Transfer of work, October 1987 to September 1988, The Netherlands.
[3] Ontario Ministry of Agriculture and Food, Trenton, Ont.

INTRODUCTION

The Vineland Research Station was formed in 1960 with the amalgamation of the Dominion Entomological Laboratory in Vineland Station (established in 1911) and the Dominion Laboratory of Plant Pathology in St. Catharines (established in 1912). The two facilities moved to a new office–laboratory–greenhouse complex in 1968 on the property of the Ontario Ministry of Agriculture and Food Horticultural Experiment Station at Vineland Station. The Smithfield Experimental Farm, located 8 km west of Trenton, was administratively linked to Vineland in 1975.

The mandate of the research station is crop protection, with particular reference to horticultural crops. The research programs are multidisciplinary and are coordinated under three main commodity groups: tree fruits, ornamentals, and vegetables. The principal objective of the three components is the development of alternative pest control strategies that will permit a reduction in the use of chemical pesticides while maintaining an acceptable quality of crop. The research activities at Vineland are closely linked to the horticultural production research of the provincial establishment. The Smithfield Experimental Farm performs horticultural production and processing research, as well as pest control research in collaboration with Vineland. In 1988 Smithfield was identified as the primary site for the clonal repository of the Plant Gene Resources of Canada program, and the collection of genetic material has begun.

The combined Vineland–Smithfield establishment has a professional staff of 25 and an operating budget of $675 000. The Vineland facility has 30 ha of research farm while Smithfield operates 121 ha. Both establishments also do work on private growers' properties.

This report summarizes some of the research results from the station in 1988; more detailed information can be obtained from the publications listed at the end of this report. For more information on these or other research projects, or for copies of this report, please write to the Director, Research Station, Research Branch, Agriculture Canada, Vineland Station, Ont. L0R 2E0; Tel. (416) 562-4113.

D.R. Menzies
Director

ENTOMOLOGY

The effects of two sterol-inhibiting fungicides on pests and beneficial arthropods on apple. Populations of some pests and beneficial arthropods were monitored for two growing seasons in a McIntosh apple orchard that had received applications, at 2-week intervals, of two sterol-inhibiting fungicides, bitertanol and flusilazole. High rates of fusilazole were associated with increased numbers of European red mite and increased numbers of predacious mite species, *Typhlodromus caudiglans* Schuster. Trees receiving a high rate of bitertanol had fewer European red mites and predacious mite species. Fungicides did not influence the oviposition of spotted tentiform leafminer or the number of leafminer larvae in May and June 1985. However, in September 1985 fewer leafminer pupae in plots were treated with the two lower rates of flusilazole and more larvae in plots were treated with the high rate of bitertanol, relative to trees sprayed with captan. In 1986 more leafminer eggs in plots were treated with the low rate of bitertanol compared with captan and nonsprayed trees. However, by 24 June, all treatments showed similar levels of leafminer larvae and pupae. Populations of *Pholetesor ornigis* were generally higher in trees treated with flusilazole relative to nonsprayed and captan-treated trees. Fungicides had no apparent effect on populations of white apple leafhopper.

Monitoring Pholetesor ornigis, a parasite of the spotted tentiform leafminer. The effect of trap location on the number and sex ratio of adult *P. ornigis* (Weed) caught on yellow sticky traps was examined in Ontario from 1982 to 1985 during the spring and first-summer activity periods in one experimental orchard and five commercial orchards. In the first experiment, traps placed within the tree canopy in the peripheral zone caught more *P. ornigis* than traps placed above, below, and within the tree canopy, as well as those placed between adjacent trees in the peripheral and

interior zones of the orchard. Traps placed above the tree in both zones caught less than 1% of all parasites trapped. In the second experiment, traps placed within the tree canopy in the interior zone caught more male, female, and total *P. ornigis* than traps placed below the tree in the interior zone and within and below the tree in the peripheral zone during both the spring and periods of first-summer activity. The results suggest that the spatial distribution of male and female parasites changes between the spring and periods of first-summer activity. Trap location did not affect the sex ratio of trap catches. The percentage of males in trap catches from an orchard ranged from 75.6 to 96.4 during the two activity periods, whereas estimates of the percentage of males in the population from an orchard ranged from 40.0 to 63.0.

The effect of three insect growth regulators on spotted tentiform leafminer. Most treated eggs hatched, but larvae died in the early instars. High larval mortalities also occurred when treatments were applied to the foliage before oviposition. Treatments applied to larvae, especially older larvae, were less toxic than those applied to eggs. In the field, control was similar whether insecticides were applied during egg deposition, during first hatch of eggs, or against early-instar larvae. Applications during egg deposition are suggested as optimal for control. Control of spotted tentiform leafminer with insect growth regulators was equivalent to that obtained with deltamethrin or methomyl. Residues of diflubenzuron and triflumuron, applied prebloom, persisted until leaf drop 19 weeks later. Residues of teflubenzuron applied in May were toxic to larvae into October.

Influence of mass trapping on populations of spotted tentiform leafminer Mass trapping for control of spotted tentiform leafminer was evaluated during 1986 in one experimental orchard near Jordan Station, Ont., and three experimental orchards in Norfolk County, Ont. Multi-Pher II traps were used to trap adult males, and Vineland traps were used to monitor adult activity and to obtain a measure of the effect of mass trapping on adult male abundance. In the experimental orchard, Vineland trap catches were similar in the trapped and control plots. In two of the three commercial orchards, Vineland trap catches were smaller in the trapped plots during one of the three yearly periods of activity. Preadult leafminer density was significantly lower in the trapped plots than in the control plots on three of the seven sample dates in the experimental orchard, whereas in the commercial orchards, where up to 91 times as many adult males were trapped per plot per activity period, preadult density was lower in the trapped plots only in one orchard on one sample date.

NEMATOLOGY

Xiphinema rivesi, a vector of tomato ring spot virus in grape. X. rivesi was recovered from all nematode-containing samples taken from the root zone of grapevines that were either healthy or infected with tomato ring spot virus (TmRSV) in 21 European hybrid vineyards in the Niagara Peninsula. *X. americanum* was found in one of those samples. TmRSV-infected vineyards occurred on all soil types, and the virus was transmitted to bait plants grown in soil from infected vines. The results indicated that *X. rivesi* is the principal vector of the virus in the area studied and that this nematode is associated with a wider range of soil types than was previously reported.

Control of Pratylenchus penetrans by oxamyl. Oxamyl was applied to both cut and uncut potato tubers in aqueous solutions of 1000–32 000 µg/mL. Emergence in greenhouse pots was delayed for a day or more after soaking cut tuber pieces in 32 000 µg/mL. After 10 weeks, plant growth was greater, relative to the control, when *P. penetrans*-infested soil was planted with cut tubers soaked for 20 min in 32 000 µg/mL. Soaking for 40 min did not increase nematode control nor did it affect plant growth. Oxamyl applied to tubers at 1000 µg/mL reduced the number of *P. penetrans* in the soil by 20% and in the roots by 35%; at 32 000 µg/mL, the number of *P. penetrans* in the soil was reduced by 73–86% and in the roots by 86–97%. The number of *P. penetrans* did not increase in the roots of plants developed from the cut tubers soaked in 32 000 µg/mL over a period of 10 weeks, but the number of lesion nematodes had begun to increase in the soil.

Influence of strip tillage on yield, diseases, and nematodes of tomatoes. Strip tillage into killed rye (*Secale cereale* L.) and oats (*Avena sativa* L.) cover crops was evaluated as a production system for machine-harvested processing tomatoes (*Lycopersicon esculentum*

Mill.). No effect of tillage on yield was found for 2 out of 3 years. Yield was reduced in the third year in strip-tilled rye plots because of low transplant vigor, and, possibly, low-temperature injury. Populations of plant parasitic nematodes were stimulated by rye and strip tillage. Bacterial diseases were increased by strip tillage in one season. Long-term evaluation of conservation-oriented systems is required to determine effects on yield, nematodes, and diseases.

Longidorus elongatus as a virus vector. A population of *L. elongatus* from Ontario was shown to transmit efficiently English and Scottish isolates of raspberry ringspot virus and a Scottish isolate of tomato black ring virus (TBRV). No transmission occurred with English or German isolates of TBRV, but the occasional transmission of an Ontario isolate of peach rosette mosaic virus was detected. The transmission results and the morphometric indices for this nematode population indicated that it was similar to populations of the nematode found in Great Britain.

PLANT PATHOLOGY

Influence of temperature and wetness duration on infection of peach and sweet cherry fruits by Monilinia fructicola (Wint.) Honey. Nonwounded peach and sweet cherry fruits were inoculated with a conidial suspension of *M. fructicola* at temperatures of 15–30°C at 2.5°C intervals and wetness durations of 3–15 h (peach) or 6–18 h (cherry) at 3-h intervals. Both peach and cherry had an increased incidence of fruit infection with duration of increased wetness over the range of temperatures tested. Optimum observed temperature for cherry fruit infection was 20–22.5°C, with greater than 80% infection after 15 h of wetness. After 18 h of wetness, infection was greater than 80% at all temperatures except 30°C. Optimum observed temperature for infection of peach fruit was 22.5–25°C. Greater than 70% infection occurred after 12 h at all temperatures except 17.5 and 30°C. Nontransformed polynomial and logistic equations for peach and cherry, respectively, were chosen as the best regression models to describe the incidence of fruit infection as a function of temperature and wetness duration. The Analytis Beta model was used to describe the effect of wetness duration on the incubation period for sweet cherry. The incubation period decreased with increasing wetness duration. All models had significant coefficients, and the experimental runs were similar within fruit species.

Tomato spotted wilt virus in greenhouse crops in Ontario. Since 1984 tomato spotted wilt virus (TSWV) has caused production losses in 32 greenhouses, principally in the Niagara Peninsula and southwestern Ontario. TSWV was identified on the basis of symptoms in assay hosts, immunosorbent electron microscopy, and enzyme-linked immunosorbent assay (ELISA). Based on representative samples, the most frequently infected crops were New Guinea impatiens, gloxinia, tomato, cineraria, cyclamen, and calceolaria. Other infected crops included begonia, marigold, ageratum, dahlia, calendula, and primrose. All diseased crops were infested with the vector, *Frankliniella occidentalis* (Pergande). In some cases, TSWV outbreaks were associated with the introduction of infected New Guinea impatiens. Complete eradication of the virus has not been possible, except when the virus was detected early and the thrips population levels were low.

Fungicidal control of phoma canker of parsnip. The minimum concentrations of chlorothalonil, maneb, mancozeb, fixed copper, and iprodione, with active ingredient (a.i.), that inhibited germination of *Phoma complanata* in vitro were 0.1, 10, 10, and 100 µg/mL, respectively. In greenhouse tests using parsnip plants of the susceptible cultivar Harris Model, these fungicides with a.i. applied at 10.8, 20.0, 13.6, 16.3, and 4.0 mg per plant, respectively, significantly reduced the severity of *P. complanata* foliar disease. Field studies, conducted at three widely separated locations in 1986, evaluated chlorothalonil and mancozeb with a.i. at a rate of 1.4 and 1.8 kg/ha, respectively. Generally, final foliar disease severity ratings, area under the disease progress curve, and canker incidence were significantly less in fungicide-treated plots than in untreated plots, whereas yield of harvestable parsnips (plants with tops remaining) was significantly greater in treated plots than in untreated plots at two of the sites. Residue levels of chlorothalonil and 4-hydroxy-2,5,6-trichloroisophthalonitrile, the toxic metabolite of chlorothalonil, did not change significantly between 3, 5, 7, and 10 days after the last fungicide application.

Residues of chlorothalonil and its metabolite 7 days after the last fungicide application ranged from 0.13 to 0.35 and from 0.021 to 0.030 µg/g of root tissue, respectively. This was the first report of the chemical control of phoma canker on parsnip.

Influence of graft unions on the infection of scions by tomato spotted wilt virus. DeChaunac scions grafted onto Sonona, SO4, 5BB, 3309, 4453, Concord, and DeChaunac rootstocks were planted along with own-rooted vines in a commercial vineyard with a high incidence of tomato ring spot virus infection. All grafted vines remained healthy over seven growing seasons, while own-rooted DeChaunac became infected during and following the second growing season. Since the virus was undetectable in all grafted understocks, including susceptible DeChaunac, it would appear that the graft union influences translocatory movement and multiplication of the virus, thus preventing infection of susceptible scions. Yield reductions were apparent in DeChaunac grafted on Concord, SO4, 5BB, and 4453 understocks, while total sugar, acid, and pH levels of the juice were unaffected.

Report of a previously unidentified potexvirus in Ontario. A previously unidentified potexvirus was isolated from common burdock (*Arctium minus* (Hill) Bernh.) in the Niagara Peninsula of Ontario. Infected plants showed a bright yellow mosaic mottling and stunting of growth. The virus was readily transmitted mechanically but was not seed borne. On the basis of studies on the range of the host, no similarity could be found between this virus and other described potexviruses, although immunodiffusion tests revealed serological relatedness with potato aucuba mosaic and clover yellow mosaic viruses. The virus crude sap from *Chenopodium quinoa* was infective to a dilution end point of 10^{-6}. The thermal inactivation point was 58°C, and longevity in vitro at 20°C was up to 13 weeks.

Variation with maturity of peach fruits to Monilinia fructicola. Fruit of the peach cultivars Redhaven and Loring was harvested weekly beginning in early June and continuing to full ripeness, and was inoculated under controlled conditions with *Monilinia fructicola* at a range of 10^3–10^6 conidia per millilitre. In both years of the study, fruit was susceptible to infection at all inoculum concentrations for 2–4 weeks in June. At pit hardening it became resistant to infection at all inoculum concentrations. Fruit again became increasingly susceptible to infection approximately 2 weeks before full ripeness.

Suppression of Sclerotinia sclerotiorum on celery. At 1°C, the growth in vitro of *S. sclerotiorum* (Lib.) de Bary on celery extract agar was most suppressed in a storage atmosphere containing 7.5% CO + 1.5% O_2, but only slightly suppressed in 4% CO_2 + 1.5% O_2 or in O_2 alone, compared with normal air. Watery soft rot caused by this fungus was severe on celery (*Apium graveolens* var. *dulce*) stored in normal air for 2 wk at 8°C. A comparable severity took 10 weeks to develop at 1°C. At 8°C the suppression of this disease was the greatest in atmospheres of 7.5–30% CO + 1.5% O_2, but only slightly reduced in 4–16% CO_2 + 1.5% O_2 or in 1.5–6% O_2.

SMITHFIELD EXPERIMENTAL FARM

Monitoring apple maggot, Rhagoletis pomonella (Walsh). The standard apple maggot trap, consisting of a Zoecon prebaited yellow board and two red spheres, which is currently used in Ontario, was more effective in general performance than the Ladd trap, consisting of a yellow panel with a red hemisphere on each side. Odor-enhanced lures increased the effectiveness of both the Ladd traps and the red spheres in trapping apple maggot flies under some conditions.

Performance of scab-resistant apple cultivars. Scab-resistant apple cultivars developed from the breeding program initiated in 1949 at the Central Experimental Farm, Ottawa, Ont., include Macfree, Moira, Trent, Britegold, Murray, Richelieu, and Rouville. Three additional scab-resistant selections, O-637, O-654, and O-662, show promise as fresh-market and processing apples. Murray was the highest yielding cultivar, but Moira had the highest cumulative yield efficiency on all rootstocks. Britegold and Richelieu had low yields. The fruit of Macfree, Moira, Murray, Richelieu, and O-662 was smaller than that of McIntosh, whereas the fruit of Rouville was larger. Trent had the best storage life, retaining firmness for at least 6 months at 2°C. The fruit of Macfree, O-637, O-654, and O-662 was resistant to cedar apple rust, although the leaves and the fruit of all cultivars was

susceptible to quince rust. Britegold, Macfree, and O-637 showed good resistance to fire blight. These cultivars offer a range in harvest dates from late August for Murray to late October for Trent.

Texture differences in applesauce from various cultivars. Canned sauce made from various cultivars of apples differs characteristically in texture. Textural variations of this kind are important commercially. Microscopic study of the raw fruit of McIntosh, Red Delicious, Northern Spy, Spartan, and Idared demonstrated differences in the nature of the parenchyma cell wall materials. The degree to which they dissociate and possibly recombine in the case of certain cultivars of late storage fruit determines the degree of cell separation contributing to the main textural quality of applesauce, usually referred to as coarseness. In addition to these cell wall binding materials, the results indicated that lesser contributors to sauce texture could include the fruit's vascular system and the physical presence of starch granules in the cells of early-storage fruit.

Improving juice yield from apples. Yields of apple juice on pressing have been increased from 72 to 82% by using improved prepress conditions. These include processing the apples at harvest maturity rather than later out of storage, reducing the grind size, and treating the crushed apples with a macerating enzyme before pressing. An additional benefit was a much faster and better compaction of fines during juice settlement. This benefit was due mainly to the use of fruit at harvest maturity, which also resulted in a juice of lighter color, although it was slightly lower in soluble solids. The slight lowering of soluble solids content was not a problem, because the minimum requirement for commercial processing was met with the cultivars tested in 1987 and 1988. The 10% increase in juice yield will improve the efficiency of the operation, especially in orchards established for juice production, where harvest date can be scheduled for immediate juice pressing.

Pea cultivars for processing. In 1987 and 1988, 16 and 13 cultivars, respectively, of processing peas were evaluated for field performance and quality after freezing. The cultivars required from 634 to 914 heat units to mature. The high temperatures of 1988 accelerated the maturity. Puget ranked highest in yield both years and had the highest percentage of peas in sieve sizes 3, 4, and 5, although it ranked poorest in cooking quality. Wavertop and FR9888 were the cultivars with the best cooked quality, although Wavertop was hard to shell and was low yielding. Bolero, the standard, was intermediate in all factors evaluated.

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Western Region
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PREFACE

The Western Region consists of 14 research stations, four experimental farms, and eight substations in Manitoba, Saskatchewan, Alberta, and British Columbia. In 1988 the region employed a staff of 1256 with a budget of $82.9 million. Each research station has an advisory committee for consultation on research priorities.

The region participates in many joint ventures with provincial governments, universities, producer associations, commodity associations, and agribusiness. Notable examples are the Economic and Regional Development agreements with Manitoba, Saskatchewan, and British Columbia; the Alberta Farming for the Future program; and the Western Grains Research Foundation.

Research is conducted in four program areas: soil and water resources, crop production, livestock production, and food processing and storage. The goals of the research programs are to solve production problems and to develop new opportunities for Canadian farmers in domestic and international markets. The following highlights of 1988 illustrate the research programs of the region.

The 1988 crop year was one of the driest years on record in the southern prairie region. During the year the region also responded to the infestation of cereal grains by the Russian wheat aphid, the threat to honey bees presented by tracheal and verroa mites, and off-flavor in stored potatoes.

Excessive tillage associated with traditional practices has led to degradation and erosion of prairie soils. However, the physical characteristics of soils can be improved by continuous cropping and reduced-tillage practices. Economic analysis showed that reduced summerfallow tillage can provide economic returns within 5% of conventional summerfallow practices.

HY368, a new red-seeded Canadian Prairie Spring wheat was registered and accepted for market evaluation by the Canadian Wheat Board. HY368 has a hard kernel with improvements in milling and baking quality compared with the variety HY320. Frank triticale was registered. This cultivar provides a higher yield and test weight, compared with earlier cultivars. Corn inbred CL30 was released to Canadian seed corn companies. CL30 combines early maturity and good stalk strength. Sunflower hybrids MRS37 and MRS40 were released to industry. MRS37 is an early-maturing hybrid with resistance to downy mildew and other diseases. MRS40 is a short-statured, high-yielding hybrid with resistance to verticillium wilt.

A breakthrough in the genetic manipulation of *Brassica juncea* allows the breeding of oilseed mustard with a quality comparable to that of canola. Mustard is resistant to blackleg disease and is well adapted to the drier parts of the prairie region.

Tetracan Russian wild ryegrass was registered. Tetracan has a large seed, with improved establishment vigor. James and Arthur Dalhurian wild ryegrass were registered. This quick-growing forage grass is suitable for short rotations. It is a useful starter grass with long-lived perennial grasses.

MP889, a field pea with high fiber content, was registered and released to serve the rapidly expanding pea fiber market. MP954, a large-seeded, high-yielding field pea suitable for the soup market, was registered and released.

A plan for the control of codling moth was approved by fruit growers in the southern-interior region of British Columbia. This sterile insect release program is expected to eradicate the codling moth within 5 or 6 years.

The northern strawberry breeding program was completed with the release of four selections, which are earlier and higher yielding than the cultivar Protem. A new winter-hardy, everblooming light pink rose cultivar was released to the nursery trade.

Economic analyses of beef cow herd productivity showed that the benefits of producing a large calf from a large-framed cow outweighed the additional cost of winter feed and the cost of pasturing fewer cows. Handling methods that cause bloody thighs in slaughtered chickens were identified, and recommendations for reducing its incidence were made to the industry.

The use of electronic probes to grade beef carcasses provided only marginal improvement in the estimation of carcass lean yield, compared with conventional grading. Recommendations for changes to beef grades included more complete ribbing of carcasses, fewer maturity grades, and reinstatement of marbling.

D.G. Dorrell was appointed director general of the Western Region, replacing W.L. Pelton who transferred on special assigment to the position of Canadian project director of Research Branch international aid projects in Pakistan, Tanzania, and Malaysia. D.G. Dorrell was formerly director at Lethbridge Research Station. P.A. O'Sullivan was appointed acting director and D.L. Struble was appointed acting assistant director at Lethbridge Research Station. D.M. Bowden retired as director at Summerland Research Station, and D.B. Cumming was appointed acting director at Summerland Research Station.

For further information concerning programs, contact the research stations directly. Address communications on planning and priorities to Agriculture Canada, Research Branch, Western Region, Sir John Carling Building, Ottawa, Ont. K1A 0C5; Tel. (613) 995-7084.

D.G. Dorrell
Director General

PRÉFACE

La Région de l'Ouest comprend 14 stations de recherches, 4 fermes expérimentales et 8 stations satellites situées au Manitoba, en Saskatchewan, en Alberta et en Colombie-Britannique. En 1988, la région gérait un effectif de 1 256 personnes et un budget de 82,9 millions de dollars. Chaque station de recherches possède un comité qui fournit des conseils sur les priorités de la recherche.

La région participe à de nombreux projets conjoints avec les provinces, les universités, les groupements de producteurs, les associations du secteur primaire et l'agrinégoce. À titre d'exemples, on peut citer sa participation aux ententes de développement économique et régional (EDER) conclues avec le Manitoba, la Saskatchewan et la Colombie-Britannique, ainsi qu'au programme *Farming for the Future* (L'Agriculture de demain) de l'Alberta et à la Fondation de recherches sur le grain de l'Ouest.

Les recherches portent sur quatre domaines, notamment les ressources en sol et en eau, les productions végétales, les productions animales, de même que la transformation et la conservation des aliments. Leurs objectifs globaux consistent à trouver des solutions aux problèmes de production et de nouvelles possibilités pour les agriculteurs canadiens sur les marchés nationaux et internationaux. Les faits saillants qui suivent donnent un aperçu des programmes de recherches de la Région en 1988.

La campagne agricole de 1988 a été marquée par l'une des pires sécheresses de l'histoire de la région du sud des Prairies. Cette dernière a également dû composer avec l'infestation de pucerons russes du blé, avec la double menace de l'acarien de l'abeille et du varroa, et aussi avec le problème des pommes de terre éventées en entrepôt.

Le labour excessif associé aux pratiques d'exploitation traditionnelles a causé la dégradation et l'érosion des sols dans les Prairies. Toutefois, il est possible d'améliorer les caractéristiques physiques des sols en adoptant un régime de monoculture et de labour minimal. Des analyses économiques ont révélé qu'une réduction du travail du sol sur les jachères ferait baisser les rendements d'à peine 5 % par rapport aux méthodes d'exploitation traditionnelles.

Le HY368, un nouveau cultivar de blé roux de printemps des prairies canadiennes, a été homologué et accepté pour l'évaluation commerciale par la Commission canadienne du blé (CCB). Sa graine est dure et il présente une qualité meunière et boulangère supérieure à celle du HY320. La variété de triticale Frank a également été homologuée. Son rendement et son poids à l'essai dépassent ceux des cultivars antérieurs. La lignée autofécondée de maïs CL30, qui se caractérise par sa précocité et la résistance de sa tige, a été mise à la disposition des marchands grainetiers du Canada.

Les hybrides de tournesol MRS37 et MRS40 ont été mis au commerce. Le premier se caractérise par sa précocité et sa résistance au mildiou et à d'autres maladies. Le deuxième se distingue par sa petite taille, son rendement élevé et sa résistance à la flétrissure verticillienne.

Les progrès accomplis dans le domaine de la manipulation génétique du *Brassica juncea* permettront de produire une moutarde de qualité comparable à celle du colza canola. La moutarde résiste à la jambe noire et elle est bien adaptée aux zones sèches de la région des Prairies.

L'élyme de Russie Tetracan, une variété à grosse graine qui offre une vigueur d'établissement améliorée, a été homologuée. Les variétés James et Arthur d'élyme de Mongolie (*Elymus dalhuricus*) ont également été homologuées. Ce sont des graminées fourragères à croissance rapide qui sont utilisées en régime de court assolement et qui constituent de bonnes plantes de départ pour les graminées vivaces de longue durée.

Le MP889, un pois de grande culture à haute teneur en fibres, a été homologué et mis au commerce pour répondre aux besoins d'un marché en pleine expansion. Le MP954, un pois de grande culture à grosse graine et à haut rendement qui se prête à la préparation de soupes, a été homologué et mis au commerce.

Un plan de lutte contre la pyrale de la pomme a été approuvé par les producteurs de fruits de la région du sud de l'intérieur de la Colombie-Britannique. Ce plan, qui consiste à effectuer des lâchers d'insectes stériles, devrait permettre d'éliminer la pyrale en 5 ou 6 ans.

Le programme d'amélioration de la fraise du nord a pris fin avec la mise au commerce de quatre sélections qui surpassent le cultivar Protem au chapitre de la précocité et du rendement. Un nouveau cultivar remontant de rose, de couleur rose pâle, résistant à l'hiver, a été mis à la disposition des pépiniéristes.

Des analyses économiques de la productivité des troupeaux de vaches de race à viande ont démontré qu'il était plus avantageux d'utiliser des vaches à grand développement pour la production de veaux, et ce même en tenant compte des coûts supplémentaires qu'occasionnent les rations d'hiver et la diminution du nombre de vaches en pâturage. Par ailleurs, on a cerné les méthodes d'abattage qui sont à l'origine des taches sanguinolentes présentes sur les cuisses des poulets abattus et on a recommandé des mesures au secteur afin de réduire l'incidence de ce problème.

L'utilisation de sondes électroniques pour classer les carcasses de boeuf n'a fait qu'améliorer légèrement l'évaluation du rendement en viande maigre si l'on compare avec les méthodes de classement traditionnelles. Parmi les changements qu'on a recommandé d'apporter au système de classement du boeuf, mentionnons l'incision plus complète des carcasses, la réduction du nombre de classes d'âge et le rétablissement du critère de persillé.

M. D.G. Dorrell a été nommé directeur général de la Région de l'Ouest à la place de M. W.L. Pelton. Par suite d'une affectation spéciale, ce dernier s'est vu confier le poste de directeur des projets canadiens d'aide internationale au Pakistan, en Tanzanie et en Malaisie. M. Dorrell a déjà occupé le poste de directeur de la Station de recherches de Lethbridge. M. P.A. O'Sullivan a été nommé directeur intérimaire et M. D.L. Struble, directeur adjoint par intérim de la Station de recherches de Lethbridge.

M. D.M. Bowden a quitté son poste de directeur de la Station de recherches de Summerland pour prendre sa retraite et M. D.B. Cumming a été nommé directeur par intérim de la Station.

Pour de plus amples renseignements sur les programmes, il suffit de communiquer directement avec les stations de recherches. Pour obtenir des précisions sur la planification et les priorités, on doit s'adresser à la Direction générale de la recherche du ministère de l'Agriculture du Canada, Région de l'Ouest, édifice Sir John Carling, Ottawa (Ont.), K1A 0C5; tél. (613) 995-7084.

D.G. Dorrell
Directeur général

Research Station, Brandon, Manitoba

PROFESSIONAL STAFF

Administration

E.E. Swierstra, B.S.A., M.S.A., Ph.D.	Director
T. Baran[1]	Administrative Officer
S. Ramsay, B.Sc.(Agr.)	Information Officer
R.J. Bomford, B.Sc., M.Sc.	Computer System Manager
Vacant[2]	Librarian
E.G. Smith, B.S.A., M.Sc., Ph.D.	Economist, Economic Regional Development Agreement (ERDA)

Animal Science

G.W. Rahnefeld, B.Sc., M.Sc., Ph.D.	Head of Section; Beef cattle breeding
A.G. Castell, B.Sc., M.Sc., Ph.D.	Swine nutrition
R.L. Cliplef, B.Sc., M.Sc., Ph.D.	Meats physiology
G.W. Dyck, B.S.A., M.Sc., Ph.D.	Swine reproductive physiology
R.R. Grandhi, B.V.Sc., M.Sc., Ph.D.	Swine nutrition
D.L. Grinwich, B.Sc., M.Sc., Ph.D.	Swine reproductive physiology
R.M. McKay, B.Sc., B.S.A., M.Sc., Ph.D.	Swine genetics

Plant and Soil Science

L.D. Bailey, B.S.A., M.Sc., Ph.D.	Head of Section; Soil–plant relationships
P.N.P. Chow, B.Sc., M.Sc., Ph.D.	Herbicides and weed control
D.T. Gehl, B.S.A., M.Sc.	Agronomy (ERDA)
C.A. Grant, B.S.A., M.Sc., Ph.D.	Soil management
W.G. Legge, B.S.A., M.Sc., Ph.D.	Barley genetics
S. Plett, B.S.A., M.Sc., Ph.D.	Corn breeding
J.M. Sadler, B.Sc., M.Sc., Ph.D.	Soil fertility and plant nutrition
R.G. Simons,[3] B.Sc., M.Sc., Ph.D.	Forage agronomy
M.C. Therrien, B.Sc., Ph.D.	Barley breeding

Departure

E.D. Simundsson, B.A., M.L.S. Transferred to Canadian Grain Commission, Winnipeg, October 1988	Librarian

[1] Appointed January 1988.
[2] Seconded from Libraries Division, Corporate Management Branch.
[3] On transfer of work at the School of Botany, Cambridge, England, December 1988 to December 1989.

INTRODUCTION

Research programs at the Brandon Research Station focus on beef cattle breeding; swine genetics, reproductive physiology, nutrition, and meat physiology; barley and corn breeding; forage crop management; and soil management and crop production. Much of the research is multidisciplinary. The station occupies 708 ha and leases another 585 ha for research work and feed production for the large beef and swine herds.

In 1988 Mr. T. Baran joined the staff as administrative officer, Dr. R.G. Simons started a 1-year postdoctoral transfer of work at Cambridge, England, and E.D. Simundsson transferred to the Canadian Grain Commission in Winnipeg.

Highlights of research include the finding that hide thickness in swine carcasses is influenced by breed or cross and gender and that these differences need to be taken into account when grading skinned hog carcasses; that the incidence of anestrus in primiparous sows is affected by the type of housing but not by exposure to mature boars; that the most successful method of phosphorus application in flax production is placement 2.5 cm directly below the seed at planting; and that current nitrogen fertilizer recommendations for barley in Manitoba may need revision to differentiate between older malting and newer higher yielding feed types, which were shown to require 50 kg/ha (40%) more applied nitrogen on average to achieve maximum grain yield. Many of the findings were published from the long-term beef-breeding program designed to determine the contribution that the Continental (exotic) breeds of cattle can make to the Canadian beef industry.

The short reports that follow give results of recent research as well as an indication of the type of studies that are in progress. Further information can be obtained from the publications listed at the end of these reports or by direct contact with individual scientists. Correspondence or requests for reprints should be addressed to the Research Station, Research Branch, Agriculture Canada, Box 610, Brandon, Man. R7A 5Z7; Tel. (204) 728-7234.

E.E. Swierstra
Director

ANIMAL SCIENCE

Beef cattle

Live body measurements of 10 first-crosses of beef cows raised in two environments. A 6-year study compared live body measurements from 10 first-crosses of beef cows raised under semi-intensive farm-type management typical of the parkland region (Brandon, Man.) versus extensive range management typical of ranching operations in the semiarid shortgrass prairies (Manyberries, Alta.). Mature Continental (exotic) crosses of cows at weaning in the fall were heavier and larger in skeletal measurements and carried less subcutaneous fat than cows of traditional British (Hereford–Angus) breeding. Nursing status did not permanently affect the skeletal measurements but did affect body weight and fat cover. Cows at Brandon achieved a greater proportion of their mature body size before their contemporaries at Manyberries did, for all traits measured.

Genotype × environment interactions for beef cow performance during lactation. Beef cow performance traits expressed during lactation were evaluated for 10 F_1 cow crosses. The crosses (genotypes) were represented by the Hereford–Angus and nine others produced by mating Charolais, Simmental, and Limousin sires with Hereford, Angus, and Shorthorn cows. Environmental differences were provided by two climatically distinct locations (Brandon, Man., and Manyberries, Alta.), with two treatments (drylot confinement versus pasture) imposed at each location during 3 consecutive years. The total data set comprised 1274 cow-calf pairs, with milk production measured for 730 lactations. Substantial year, treatment, and breed-cross effects were present ($P < 0.01$) at each location for virtually all the traits evaluated (cow weight and average subcutaneous fat, weight and fat changes during lactation, milk yield, calf growth rate, and conception rate). Substantial year × treatment interactions were also present ($P < 0.0001$). No genotype × environment

(year × breed cross and breed cross × treatment) interactions were identified at either location for preweaning growth rate of the calves, average daily milk yield of the cows, or date of conception. Location differences were large for all these traits, but rankings of the breed crosses at the two locations were in close agreement, indicating the absence of any location × genotype interactions. The ranking of breed crosses for conception rate was unaffected by treatment or year within location, but the rankings did differ between locations. At Manyberries, conception rates tended to be inversely related to average milk yield of the breed crosses; no such relationship was evident at Brandon.

Breed-cross differences in feed input for lactating beef cows. Feed input for lactation was measured over a period of approximately 120 days in drylot confinement during three consecutive summers for two herds of mature beef cows. Each herd, one located at Brandon, Man., and the other at Manyberries, Alta., included 10 breed crosses. Nine crosses were produced by mating Charolais (C), Simmental (S), and Limousin (L) sires with Hereford (H), Angus (A), and Shorthorn (N) dams. The Hereford–Angus (HA) served as the control. Data for analysis represented a total of 760 cow-years. Cow weight at the start of the test (approximately 1 June) was used to estimate basic daily feed requirements. Average subcutaneous fat at the start of the test was also considered at Manyberries. Daily feed input was adjusted at approximately 28-day intervals, with allowances increased (decreased) as required to correct for losses (or gains) of weight or fat in the drylot cows relative to contemporary lactating cows on pasture. As a result, the feed input was considerably in excess of the estimated (according to levels set by the National Research Council of Canada–National Academy of Sciences (NRCC–NAS) in 1984) daily allowances for cows of superior milking ability during the first 3–4 months of lactation. The heaviest breed cross (CN at Brandon and CH at Manyberries) consumed the most feed, whereas the lightest breed crosses (HA and LA) consumed the least. Estimated digestible energy offered the final year averaged 20% (Brandon) and 14% (Manyberries) above 1984 NRCC–NAS requirements, but these feeding levels were not sufficient to maintain body weight during lactation. Particularly large weight losses (12–29 kg) at both locations were recorded by the LN, SH, SA, and SN breed crosses, although the feed allowances for these crosses were above the averages at each station.

Swine

Level of soybean meal in pig grower diets. Barrows and gilts were fed barley-based diets containing from 4 to 20% soybean meal (SBM, 46% protein). Their responses revealed that at least 12% SBM was required for fast, efficient growth from 25 to 97 kg liveweight. Carcass attributes were improved as the dietary SBM level increased, but they tended to peak at lower levels for barrows than for gilts. Sensory evaluation showed a marked preference for pork from pigs fed the lowest SBM level. For barrows and gilts, respectively, the results favored the use of 8 and 12% SBM. Those diets contained approximately 14 and 15% crude protein, respectively.

Methionine supplementation for lentil diets. At 25–95 kg liveweight, gilts were self-fed barley diets containing 13.3% soybean meal or 40% lentils (23% protein) and 0, 0.1, or 0.2% added methionine. Increasing the dietary level of methionine did not affect ($P > 0.05$) live pig performance but did improve ($P < 0.05$) the carcass leanness of pigs fed the barley–lentil diets. There were no differences in the meat quality criteria examined in either dietary group. The results indicated the potential benefit of using a commercially available amino acid to correct an imbalance in dietary protein quality.

Measurement of 16-androstenes in mature boars of two breeds following castration. Salivary levels of 16-androstenes, a class of steroids responsible for boar taint, were determined by radioimmunoassay for six Lacombe and seven Yorkshire mature boars (1 week before and 12 weeks after castration) as well as for seven Lacombe and six Yorkshire intact boars. Results showed that the measurement of salivary 16-androstenes was not a reliable indirect method of estimating levels of boar taint in porcine fat.

Hide thickness of market-weight pigs as affected by line and sex. Two hundred and eighty purebred boar and gilt carcasses, representing two genetic lines, and 143 crossbred boar, barrow, and gilt carcasses were measured for hide thickness at three anatomical locations. A breed difference in hide thickness was

apparent. Boars had thicker hides than did gilts in the purebred carcasses and gilts and barrows in the crossbred carcasses. Gilt carcasses generally had thicker hides than did barrow carcasses. Consistent differences between fat measurements from the three anatomical locations were evident in the purebred carcasses. These differences with breed or cross and gender need to be taken into account when grading skinned hog carcasses.

Mineral metabolism during gestation in gilts fed increased dietary levels of calcium and phosphorus. The apparent absorption and retention of calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), manganese (Mn), copper (Cu), and zinc (Zn) were determined at 5, 8, 11, 13, and 15 weeks of gestation for 27 Landrace × Yorkshire gilts. These gilts were fed two dietary levels of Ca–P (0.75–0.60% versus 1.125–0.90%) in three trials. Feeding higher Ca–P levels increased ($P < 0.05$) fecal excretion of Ca, P, Mg, Mn, Cu, and Zn as well as urinary excretion of P during gestation. Urinary excretion of Mn and Cu was negligible, and urinary excretion of Zn was also very low for both treatment groups. Gilts fed higher Ca–P levels had increased absorption and retention of P, but absorption and retention of Ca and K were similar for both treatment groups. Absorption of Mg, Mn, Cu, and Zn was reduced ($P < 0.05$) by higher dietary Ca–P levels, indicating that gestation diets should be adequately supplemented with these minerals to prevent possible deficiencies from occurring.

Occurrence of estrus in sows after weaning. Two experiments used 106 primiparous sows to determine how the incidence of anestrus (no estrus within 10 days of weaning) is affected by the type of housing and exposure to mature boars. More sows were anestrous ($P < 0.10$) when housed in pairs in confinement than when housed in groups in outside lots (64.0 versus 39.5%, respectively). Exposure of sows to mature boars had no effect on the incidence of anestrus, but the duration of estrus was shorter ($P < 0.01$) for sows with constant boar exposure as compared with 5 min of daily boar exposure (1.6 versus 2.4 days, respectively).

Stimulation of puberty for gilts housed in confinement. Over a 4-year period, 483 gilts were evaluated to determine the effects of dietary intake, type of confinement pen, and breed of sire on the occurrence of puberty. Gilts were moved from a grower facility to a confinement dry sow barn at 160 days of age, housed either in group pens of eight gilts or in individual stalls, and fed at a level of dietary intake to provide either 0.4 or 0.0 kg daily gain for the first 2 weeks and 0.4 kg daily gain thereafter. The gilts were from a rotational-cross herd and sired by Yorkshire and Landrace boars in alternate years. Three hundred and fifty-seven (74%) gilts attained puberty within 60 days. Breed of sire had no effect on the number of gilts that attained puberty, but there was an interaction between breed of sire and pen type. Yorkshire-sired gilts were not affected by pen type, with 77 and 75% of the group- and stall-penned pigs, respectively, attaining puberty. For Landrace-sired gilts, however, more stall- than group-penned (86 versus 56%, respectively) pigs attained puberty ($P < 0.01$). There was no breed difference in the average number of days to puberty, but this trait was affected by both pen type and dietary intake. More stall- than group-penned gilts attained puberty ($P < 0.01$) within 2 weeks of movement (59 versus 35%, respectively). The effect of dietary intake occurred only with the stall-penned gilts; fewer attained puberty between 2 and 26 days after movement. These results would indicate that when gilts are selected for the breeding herd at market weight and are moved to a different confinement facility, the efficiency with which they attain puberty is influenced by breed of sire, type of pen, and dietary intake, with all of these differences being apparent within 1 week of movement.

PLANT AND SOIL SCIENCE

Cereals

Corn breeding. Five years of data collected for the Manitoba Corn Committee were used to produce a more accurate formula for predicting the number of corn heat units (CHU) accumulated before maturity of corn hybrids. Present CHU predictions are based on days to silking and moisture at harvest time relative to those of Pioneer 3995, whose rating is set at 2151 CHU. The new formula is based on the rate at which grain dries down for nine different hybrids as measured from 1984 to 1988 at Brandon, Morden, and Ridgeville. The new predictor shows less interaction of genotype by environment, as no one hybrid has a fixed CHU value across locations and years.

The actual number of CHU accumulated to the measurement of grain moisture is used to determine the CHU rating of the hybrid. Because the prediction is based on grain-moisture levels, it better reflects the actual maturity date of the hybrids when grown in Manitoba. Thus, published CHU maps will be much more closely related to actual maturity and harvest dates. When predicting time to 30% grain moisture, CHU ratings will range from 150 to 250 CHU higher than when using the present rating system.

Forages

Alfalfa emergence under low-temperature seeding and deep seeding. Experiments were performed to establish possible differences in the emergence of seedlings of eight alfalfa cultivars from two seeding depths (1 and 4 cm) at three low or medium temperatures (8, 12, and 16°C). Algonquin had the greatest final emergence as a proportion of the viable seeds sown, and Banner and Beaver had the least. It is possible, however, that seed lots could vary in this respect. Vernal and Iroquois were more affected by increased seeding depth than was Citation. There was no correlation with seed weight. Citation was less affected by soil temperature than were Banner and Saranac. The different responses of the cultivars to temperature and seeding depth suggest that plants can be selected for emergence at low temperature and tolerance for deep seeding.

Soil management and crop production

Phosphorus fertilizer placement studies in flax. In a series of experiments, flax was grown on calcareous and noncalcareous Orthic Chernozemic soils, low in sodium bicarbonate-extractable phosphorus (P), to evaluate four placement methods using six rates of mono-ammonium phosphate fertilizer applied at seeding. Over a 5-year period, soil type, broadcast application of P fertilizer, and banding low rates of P fertilizer in the seed row with the seed had no significant effect on growth, seed yield, and P uptake in flax. Crop emergence was reduced when P fertilizer was banded in the seed row with the seed at rates of 15 kg/ha or more. Poor emergence of the crop reduced seed yield and P uptake; when P fertilizer was applied by this method at rates of 15 to 25 kg/ha, seed yield was reduced by 38–62%. The flax responded by increasing growth, seed yield, and P uptake when P fertilizer was banded 2.5 cm below and 2.5 cm to the side of the seed or 2.5 cm directly below the seed. With both methods, similar quantities of dry matter and P uptake accumulated during the growing season, and the harvest index of flax decreased with increasing rates of P fertilizer. However, at harvest, banding P fertilizer 2.5 cm directly below the seed produced the higher seed yield and larger quantity of P removed by the crop. This greater efficiency of P use was due to higher P uptake early in the growing season, increased seed yield, and lower harvest index values.

Yield and chemical composition of soybeans and fababeans. A 3-year experiment was conducted to compare the relative yield and chemical composition of soybeans (cultivar Maple Amber) and fababeans (cultivar Ackerperle) when the crops were grown on six Orthic Black Chernozemic soils at two levels of fertility. Phosphorus (P), potassium (K), and sulfur (S) fertilizer application increased dry-matter accumulation and seed yield of both crops. At all growth stages, fababeans produced more dry matter and, at maturity, higher yields of seed, hull, and stalk compared with soybeans. However, the ratio of seed to hull to stalk for both crops was similar and constant at 3.8:1:4.7 on all soils and at both levels of fertility. At the high fertility level, when the plants were flowering or in full pod, fababeans had higher nitrogen (N), P, and K concentrations than did soybeans, but both crops had a similar S concentration. At the low fertility level, both crops had similar P, K, and S concentrations. Upon maturity, soybean seeds had higher concentrations of the four nutrients. The P concentration in the hull and stalk of both crops was similar, but fababeans had a higher K concentration and soybean stalk had a higher S concentration. Soybean seed also had a higher protein content and yielded more protein per hectare than did fababean seed. These results showed that the high yield and N concentration of fababeans at flowering makes this crop ideally suited to green manuring in cereal rotations or to feeding livestock. Soybeans, on the other hand, would best serve as a seed protein crop in cereal rotations because of the high protein content in the seed.

Zinc and phosphorus nutrition of flax. Two 8-week growth chamber studies showed that high levels of magnesium and pH, but not adverse calcium to magnesium ratios, in soils can reduce the availability of zinc and

Research Station, Brandon, Man.

dry-matter yield of flax. Applications of zinc with phosphorus fertilizer increased the dry-matter yield of flax in half of the 16 soils evaluated. Response to zinc was more likely to occur in soils containing high levels of magnesium, phosphorus, and pH.

Effects of soil management on potassium and chloride nutrition of barley. Two 8-week growth chamber studies found that the dry-matter yield of barley grown in disturbed soil cores was equal to or lower than that produced in the undisturbed cores but was unaffected by the degree of soil compaction. The studies used intact and disturbed soil cores collected from fields under reduced tillage management. Disturbed soils showed a greater increase in dry-matter yield of barley in response to potassium or chloride fertilization, compared with undisturbed soils. Compaction did not influence the response to fertilization with potassium chloride.

Nitrogen fertility requirements of feed and malt barleys. Six cultivars of barley were evaluated for their responses to incremental nitrogen fertilization in a 3-year field study at three sites in Manitoba. The level of applied nitrogen required to achieve maximum grain yield was a function of available moisture and varied among cultivars. The high-yielding feed cultivars Virden and Heartland required additional applied nitrogen—an average of 50 kg/ha more than the malting cultivar Bonanza to achieve maximum grain yield. Among cultivars, a negative relationship between grain yield and grain protein content was demonstrated. These results indicated that current nitrogen fertility recommendations for barley in Manitoba may need revision to differentiate between malting types and higher yielding feed types.

Weed control. A 4-year study showed that AC 222,293 and HOE 33171 effectively controlled wild oats in cereals. These results contributed to the registration of the two herbicides for commercial use. Ester formulations of 2,4-D and 4-chloro-2-methylphenoxyacetic acid (MCPA) for control of broad-leaved weeds could be tank-mixed effectively with AC 222,293 at rates of up to 0.56 kg/ha. This would provide for broad-spectrum weed control in cereals.

Both AC 222,293 and HOE 46360 gave excellent control of wild oats, but the former did not control green foxtail. These two grass killers proved to be compatible upon tank mixing, and the mixture showed a significant improvement in green foxtail control compared with applications of AC 222,293 alone.

Addition of the adjuvants Ag-Surf, Citto-wet, or Agral 90 significantly improved the effectiveness of the herbicide DPX-R9674 in controlling lamb's-quarters and other broad-leaved weeds in spring wheat. Addition of the adjuvants CC-16255 or May & Baker Oil substantially increased control of wild oats by clethodim in flax; when ammonium sulfate was also added to the mixture, further improvements in weed control occurred.

Addition of the adjuvant KP 2100 enhanced herbicidal activity of RO-17-3664 and UBI 9076 against grassy weeds in flax, resulting in large increases in crop yield. UBI 9076 applied alone at 35 g/ha was ineffective against wild oats and green foxtail. To broaden the spectrum of weed control, RO-17-3664 could be mixed with herbicides for broad-leaved weeds such as bromoxynil and DPX-M6316, and UBI 9076 could be mixed with bromoxynil, DPX-A7881, and MCPA ester.

Lamb's-quarters are resistant to CGA 131036, a sulfonylurea herbicide for control of broad-leaved weeds. Addition of 2,4-D estamine and the adjuvant Agral 90 enhanced herbicidal activity. Addition of the adjuvant Ag-Surf at 0.5 to 1.0% (v/v) rates gave better control of volunteer flax with CGA 131036.

PUBLICATIONS

Research

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Research Station, Morden, Manitoba

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INTRODUCTION

The programs at the Morden Research Station are directed toward the development of new cultivars and the improvement of production and preservation methods for flax, sunflowers, buckwheat, field peas, new crops, potatoes, vegetables, and herbaceous and woody ornamentals. This report summarizes some of the results obtained from research conducted during 1988.

An early high-yielding oilseed sunflower hybrid and 12 early disease-resistant sunflower lines, several with bird resistance, were released. A field pea cultivar, with 17% higher seed coat content than existing cultivars, yielded an average of 19% higher than the most widely grown cultivar and was supported for registration. It is expected to have an impact on the rapidly expanding pea fiber market. A large-seeded high-yielding field pea suitable for the soup market was also released. Two flax lines developed in cooperation with the Crop Development Centre, University of Saskatchewan, have been supported for registration. An everblooming ivory pink rose, Morden Blush, was released to the nursery trade through the Canadian Ornamental Plant Foundation, and a unique scarlet red rose is being propagated for introduction.

Data were provided to support the registration of new herbicide uses for flax, buckwheat, field corn, field peas, field beans, and safflower. Agronomic studies defined optimum plant populations for sunflowers, flax, and French fried potatoes, as well as optimum seeding dates for flax. Food research has led to improved storage management practices for potatoes and to the investigation of irradiation for improving potato storage. Plant pathology research has identified tolerance of the most serious sunflower disease, sclerotinia wilt.

Further information on any of these research activities and reprints of publications listed in this report may be obtained from the Research Station, Research Branch, Agriculture Canada, P.O. Box 3001, Morden, Man. ROG 1JO; Tel. (204) 822-4471.

J.B. Bole
Director

FIELD CROPS

Buckwheat

Breeding. CM 221 buckwheat containing a semidwarf character was released as germ plasm. This character, conditioned by a single recessive gene, reduces plant height by shortening the first six internodes. The resulting plant is more resistant to lodging and to plant breakage because of the almost solid stem in the region of reduced internode growth.

Pathology. Infected seed was shown to be the source of primary infection of buckwheat by the downy mildew pathogen, *Peronospora ducometi* Siemaszko & Janow. Infected seed contained a few or numerous oospores, the overwintering sexual structure of the fungal pathogen. These were found in the calyx attached to mature seed, on the inside of the seed coat, and in the aleurone tissue. Examination of the calyx can be used as a nondestructive method to determine the oospore status of buckwheat seed, making it easier to determine the potential of buckwheat for spreading the disease.

Weed control. Imazamethabenz (AC 222,293), applied when buckwheat was 7 cm in height, controlled wild mustard with acceptable crop tolerance. The control of wild mustard with desmedipham applied at similar stages was also satisfactory.

Field corn

Weed control. Metolachlor plus cyanazine applied preplant and incorporated into the soil, followed by flamprop-methyl at the four-leaf stage, controlled both broad-leaved and grassy weeds, including wild oats.

Field peas

Breeding. Two yellow-seeded lines, MP 889 and MP 954, were supported for registration. MP 889 is a high-fiber and high-yielding line that outyielded Century, a commonly grown cultivar, by 19% in 4 years of testing. The edible fiber as expressed by the percentage of hull was 17% higher than the mean of the seven check cultivars. Edible fiber from peas is now being processed for use in various food products.

MP 954 is a high-yielding, large-seeded line with good cooking quality. In 4 years of testing, MP 954 yielded 14% higher than Century and 4% higher than Titan, a newly released cultivar. The seed of MP 954 is 21% larger than that of Century and 10% larger than that of Titan. The pedigreed seed will be increased in 1989 and 1990 for distribution to growers through the SeCan Association in 1991.

Management. Studies were conducted to improve a technique to evaluate green field pea breeding lines for resistance to color loss. Percentage of nonsoaked seed after 40 h on moist paper in petri dishes was negatively correlated with percentage of bleached seeds and positively correlated with color at last field harvest. This finding would provide the basis of a rapid evaluation technique. Further research is required to ensure that this nonsoaking characteristic is not associated with cooking quality.

Weed control. Imazethapyr (AC 263,499) applied when field peas were 10 cm in height controlled lamb's-quarters, redroot pigweed, and wild mustard, with satisfactory crop tolerance. Similar results were obtained with isoxaben and RE-40885 tank-mixed, applied preplant, and incorporated into the soil.

Field beans

Weed control. Mixtures of fomesafen and bentazon applied when dry beans were 10 cm in height controlled most broad-leaved weeds with acceptable crop tolerance. Imazethapyr was equally effective.

New alternative crops

A line of Lathyrus LS 8246 was released as germ plasm because of its low content (0.03%) of the neurotoxin β-*N*-oxalyl-L-α-β-diamino propionic acid (ODAP). Lathyrus is a very hardy, drought-resistant pulse crop with good potential for production in western Canada. The compound ODAP has been identified as a causal agent for lathyrism, a neurodegenerative disorder precipitated by excessive consumption of grass pea. This is the first reported low toxin source and will have application both in Canada and in production areas of Bangladesh, Ethiopia, and India, where concentrations of 1–1.5% are commonly found.

Weed control. Imazamethabenz controlled wild mustard in safflower. Treatments applied when the crop was 8 cm in height were more effective than treatments at the 4-cm stage.

OILSEED CROPS

Flax

Breeding. Two lines, FP 855 and FP 859, developed in the cooperative breeding program with the Crop Development Centre, University of Saskatchewan, Saskatoon, have been supported for registration. FP 855, a medium-early line, has high oil quality and is higher yielding than the medium-early cultivars NorLin, NorMan, and Vimy in late seeding. FP 859 is similar to McGregor in seed yield but is 2 days earlier maturing and has an oil content of approximately 1 percentage point higher.

In 2 years of evaluation in the cooperative test, the medium-early line FP 862 was similar to NorMan in seed yield in early-seeded tests but was much higher yielding in late-seeded tests. FP 862 is similar to NorMan in oil content but is higher in oil quality by approximately 7 iodine units.

Management. Five flax cultivars, including the four latest releases from this station, were seeded at four seeding rates in 1985, 1986, and 1987. Increases in seeding rate caused small decreases in seed weight, oil content, and iodine number, whereas lodging increased and maturity was hastened. There was little effect on volume weight, variable effect on plant height, and a large decrease in basal branching. Although the cultivars varied in their response to seeding rate, most yielded near maximum at the 600 seeds per square metre (approximately 33 kg/ha) rate.

Pathology. Seven lines from Argentina were identified with resistance to a combination of three rust races and may be new sources of genes with rust resistance. The genetics of resistance in these lines is under investigation. A study to evaluate the various components of partial resistance in 12 flax cultivars showed significant differences in the incubation period, latent period, receptivity, and pustule size between the various cultivars.

Weed control. Early treatments of sethoxydim, 7–10 days after emergence, greatly improved the control of wild oats and volunteer barley compared with later treatments. Spray nozzles oriented 45° forward also increased the efficiency of sethoxydim and fluazifop-P-butyl. When sethoxydim or fluazifop-P-butyl was tank-mixed with bromoxynil and 4-chloro-2-methylphenoxyacetic acid (MCPA), early-morning sprayings (5:00–11:00 a.m.) resulted in significantly more flax injury than afternoon or evening treatments.

Sunflowers

Breeding. An early oilseed hybrid, MRS 40, has been recommended for registration. MRS 40 yielded 4% more than the mean of four other early hybrids in the Manitoba sunflower trial. It is slightly shorter and has better resistance to verticillium wilt and to the midge insect than do most other hybrids.

Twelve sunflower inbred lines were released in March 1988, under the sunflower hybrid–inbred agreement. These lines include two nonoil types, five bird-resistant lines, and five oil-type restorer lines, which are early or have good combining ability, or both.

Management. An early- and a late-maturing sunflower hybrid were seeded in mid May and mid June at three plant densities in 1983, 1984, and 1986. Seed yields followed the same trends in each seeding date for both early and late hybrids. Yields were similar at the 30 000 and 45 000 plant densities, but lower at the 60 000 density. Plant height and oil content of the seeds increased, whereas seed weight decreased with the increase in plant density. Plant height was greater, but seed weight, oil content, and seed yield were lower in the late seeding than the early seeding.

Four oilseed sunflower hybrids, varying widely in growth habit, were grown with rows uniformly spaced at 45 cm and in a paired-row arrangement, alternating 30 cm with 60 cm, in 1986 and 1987. Soil moisture levels were adequate. The paired-row arrangement resulted in no yield advantage over uniform row spacing.

Pathology. Rhizopus head rot was widespread in sunflower fields in Manitoba perhaps because of the high levels of grasshopper damage to the heads and the above normal temperature in 1988. There were no apparent differences in susceptibility between the various hybrids in 35 fields surveyed. Rust was more severe than usual in southwestern Manitoba. Testing field collections of the rust revealed a shift in the race composition, with race 3 predominant in 1988. Sclerotinia wilt was less common than in previous years. A 3-year evaluation study of selected sunflower hybrids showed that ST330 was the least susceptible to sclerotinia wilt, followed by Challenger and DO643-11E. Other hybrids were even less susceptible in the first year of testing in 1988 and further evaluation will be conducted to confirm these results.

Weed control. Ethalfluralin plus RE-40885 applied preplant and incorporated into the soil controlled wild mustard, lamb's-quarters, and redroot pigweed. Similar results were obtained when ethalfluralin was followed by imazamethabenz at the four-leaf stage of sunflowers.

HORTICULTURAL CROPS

Ornamentals

Breeding and evaluation. In 1988 Tower poplar, released 10 years ago from Morden, was given an Outstanding Cultivar Award by the Canadian Society for Horticulture Science at their annual meeting. It was also recognized with an Award of Merit in 1983 by the Western Canadian Society for Horticulture for its exceptional performance under prairie growing conditions. Tower poplar is most useful in parks and recreational settings such as golf courses and is also useful as shelter and screen plantings for both urban and rural residences. It is very popular in both western and eastern Canada, with significant production in the midwestern United States as well.

Morden Blush was registered as a new rose cultivar. It is a low-growing, everblooming bush that combines winterhardiness with everblooming characteristics. Plants have consistently survived winters in zones 3a and 3b (Agriculture Canada Hardiness Zones). Plant height and width both average 50 cm. Field resistance to local populations of powdery mildew (*Sphaerotheca pannosa* (Wallr.:Fr.) Lèv.) and rust (*Phragmidium*) is good, whereas resistance to blackspot (*Diplocarpan rosae* Wolf) is fair. Flowers are borne on both current season or older wood and are light pink to ivory.

Inheritance models for flower color and extra petals in *Potentilla fruticosa* L. were developed by conducting controlled crosses

between various cultivars and advanced selections. Models for flower color included two whitening genes (W_1 and W_2) and two yellowing genes (Y_1 and Y_2), with the action of a bleaching gene implicated. Models with extra petals involve a two-gene switch (D_1 and D_2) to turn on the production of up to five extra petals and a modifier gene (Dm) that accounts for an additional one to five extra petals. Superior selections from the breeding program were field-planted, but establishment was poor because of heat and drought stress.

Male and female green ash trees from three different crown-shape classes were studied at various locations in the crown to identify important architectural variables. Significant differences among shape classes were found in midshoot diameter, elevation angle, shoot tip abortion frequency and daughter lateral shoot length. Differences among crown levels included shoot length, midshoot diameter, elevation angle, and daughter shoot length. Significant differences between sexes were found for shoot length, shoot tip abortion, and daughter lateral shoot length and number. Interrelationships of many architectural variables suggest that a significant change in one may lead to changes in overall crown form. Both deterministic and opportunistic growth responses are being investigated further.

Thirty selections of chrysanthemum seedlings were identified for further evaluation on the basis of early bloom, landscape value, and hardiness. Nineteen plants of *Monarda* were chosen for further evaluation, based on powdery mildew resistance, hardiness, and flower qualities. Aster cultivars (Pink Beauty, Purple Beauty, and Rose Beauty) and coralbells (Brandon Pink, Northern Fire, and White Cloud) were found superior in trials and were recommended to the industry.

Potatoes

Hollow heart. A literature review on the causes, control, and detection of hollow heart in potatoes was published. Hollow heart, a physiological disorder characterized by the development of cavities in the pith of the tubers, causes major losses for potato producers and processors. Management practices that can influence the incidence of hollow heart were identified. They include choice of cultivar, chemical treatment of seed pieces, plant spacing, rate and timing of fertilizer application, control of soil moisture, and use of plant-growth regulators. The most reliable and practical procedure developed for the nondestructive detection of hollow heart in whole tubers uses X-ray technology. Future investigations will evaluate the effect of selected management techniques to control or limit the incidence of hollow heart.

Variety evaluation. A recommendation for full license will be made to the National Potato Breeding Advisory Committee by the Prairie Potato Council and the breeders for two potato selections that showed superior performance in the Prairie Regional Variety Trials. W848, from the breeding program at the University of Wisconsin, has oval, white-skinned tubers with potential as a maincrop cultivar for potato chips. A 69868-2, from the University of Idaho breeding program, has long, heavy, russet-skinned tubers with potential for French fries and for count pack baked potatoes.

Plant population. The effect of plant population on Russet Burbank potatoes grown under rain-fed conditions in southern Manitoba from 1983 to 1987 was determined. Seed-piece population at planting ranged from 21.7 to 45.5 thousand seed pieces per hectare, and plant emergence generally exceeded 85%. Marketable tuber yields, specific gravity, and incidence of hollow heart in main-grade tubers (greater than 5 cm in diameter and less than 284 g in weight) and in tubers greater than 284 g in weight were generally not affected by plant population. However, as population increased, the number of harvested tubers increased and average tuber size decreased, with a decreased yield of tubers greater than 284 g in weight and an increased yield of tubers smaller than 5 cm in diameter. Sucrose levels, determined in only one trial, decreased as population increased.

Vegetables

Seed irradiation. Very low doses of irradiation have been reported to cause stimulatory or hormesis effects on plants. In our study over 3 years, irradiation significantly increased the germinated seedling emergence rate of broccoli, where the occurrence of 50% of final emergence was advanced by more than 1 day. In 1-year trials, 50% of final emergence was advanced by 3 days for parsnip, with no significant effect for cauliflower. No significant hormesis effects were observed on yield parameters.

Belgium endive. Chicory cultivars grown for production of Belgium endive (chicons) were

evaluated for commercial production potential under prairie conditions over a period of 3 years. Three cultivars—Zoom, Flash, and Faro—produced chicon yields of 36.5, 34.8, and 33.0 kg/m^2, respectively, under hydroponic culture. The roots required 6–8 weeks of cold storage to reach adequate maturity for forcing, with the use of water and alcohol-soluble sugars as a maturity index.

Utilization and quality

Potatoes. The effects of irradiation on the processing quality of Norchip and Russet Burbank potatoes were examined as a function of storage time and radiation dose. Samples were irradiated with cobalt-60 gamma rays to absorbed doses of 0, 0.08, 0.12, or 0.20 kGy, and then stored at 10°C and 95% relative humidity. Quality assessments were carried out at intervals of approximately 1 month. Controls all started sprouting within 120–150 days after being placed into storage. Irradiated samples did not sprout even after 278 days of storage. Sucrose content in both cultivars exhibited a marked transient increase shortly after irradiation, with subsequent return to control levels within 30 days (Russet Burbank) to 90 days (Norchip) postirradiation. Reducing sugar in both cultivars initially increased (twofold to threefold) and then returned to control levels within 90 days postirradiation. The color of potato chips of Russet Burbank and Norchip darkened during the interval between 30–60 and 90–120 days after treatment, respectively, after which the color recovered to values indistinguishable from the controls. The results demonstrate that irradiation of Manitoba grown Norchip and Russet Burbank potatoes results in excellent suppression of sprouting along with good retention of processing quality for extended periods of time.

Saskatoon berries. The influence of acetaldehyde and catechin on aqueous solutions of cyanidin 3-glucoside and aqueous and alcohol extracts of saskatoon berry was investigated. Pigment systems were analyzed periodically during storage at 23°C in the dark for absorbance spectra, high performance liquid chromatography (HPLC) profiles, and Hunterlab color values. Presence of acetaldehyde in the fruit extracts and both acetaldehyde and catechin in the cyanidin 3-glucoside model system caused a marked increase in color intensity during storage. Visible spectra of the color-intensified samples showed both a bathochromic shift and an increase in absorbance. The HPLC profiles of the acetaldehyde-treated berry extracts revealed the appearance of a new peak and the decrease of two anthocyanin peaks. Chromatograms of the cyanidin 3-glucoside solution containing acetaldehyde and catechin displayed six new peaks and loss of the anthocyanin. Addition of catechin alone had no significant effect on the color of the model or pigment extract systems. Results indicated that color intensification was due to molecular condensation involving catechin, acetaldehyde, and anthocyanin as well as other phenolic compounds in the berry extracts. Hue angle of the extracts accurately measured the color intensification reaction.

Onosmodium. Seeds of *Onosmodium hispidissimum* Mack., collected at three locations in southern Manitoba, were analyzed for seed characteristics, oil content, and fatty acid composition. Whole seed contained 16.7–18.4% oil, of which over 22% was γ-linolenic acid (18:3). The other fatty acids present in the oil were palmitic (16:0), stearic (18:0), oleic (18:1), linoleic (18:2), α-linolenic (18:3), tetraenoic (18:4), and eicosenoc (20:1) acids. The seeds of *O. hispidissimum* contained 2.8% more γ-linolenic acid, 2.6% more linoleic acid, and 4.4% less oleic acid than those of *O. occidentale* Mack., a previously characterized source of γ-linolenic acid. It constitutes a rich natural source of γ-linolenic acid and may find application in the health food and pharmaceutical industries.

Winter-hardy apples. The sugars present in 10 prairie-adapted apple cultivars were identified and quantified by high performance liquid chromatography (HPLC). Total sugar content ranged from 5.8% for Heyer No.12 to 9.7% for Breakey apples. All cultivars, except Collet (7.9%), Heyer No.12 (5.8%), and September Ruby (8.5%), had intermediate sugar content. The predominant sugar was fructose, followed by glucose and sucrose. The concentration of fructose (4.4–6.9%) and glucose (1.4–3.4%) in the winter-hardy apple cultivars was comparable to values reported in the literature for apples grown in milder climates. Compared with the reported range of 1.3–6.6%, sucrose concentration in the prairie-adapted apple cultivars was low (0.0–1.1%). The most frequently occurring minor sugar was xylose. It was quantified in all cultivars except Heyer No.12. Galactose and arabinose were present in trace amounts in 2 of the 10 cultivars studied.

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Research Station, Winnipeg, Manitoba

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J.J. Nielsen, Dr.Sc.Agr.	Smuts
R. Rohringer, Dr.Sc.Agr.	Molecular biology and biotechnology
A. Tekauz, B.Sc., M.Sc., Ph.D.	Leaf diseases
P.L. Thomas, B.S.A., M.Sc., Ph.D.	Microbial genetics, smuts

Stored Products

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R.J. Lamb, B.Sc., M.Sc., Ph.D.	Systems biology
O.N. Morris, B.Sc., M.Sc., Ph.D.	Insect pathology
P. Pachagounder, B.Sc.(Agr.), M.Sc.(Agr.), Ph.D.	Insect–plant relationships
B. Timlick,[6] B.Sc.(Agr.), M.Sc.	Economic entomology
I.L. Wise,[7] B.Sc., M.Sc.	Pesticide evaluation entomology

Departures

A.B. Campbell, B.S.A., M.Sc., Ph.D. Retired 26 March 1988	Common wheat breeding
B.E. Galka, B.Sc., M.Sc. Resigned 2 December 1988	Economic entomology
P. Jedel, B.S.A., M.Sc. Resigned 30 September 1988	Germ plasm evaluation

VISITING SCIENTISTS

H. Kawamoto, Ph.D. Natural Sciences and Engineering Research Council (NSERC) research associate, seconded from Department of Agricultural Engineering University of Manitoba March 1987–March 1989	Population ecology
M. Luo, Ph.D. NSERC visiting fellow	Insect biochemistry
F. Momen, Ph.D. Canadian International Development Agency (CIDA)/NSERC research associate Egypt, 13 July–31 December 1988	Stored grain mites
G. Newcombe, Ph.D. Uniroyal Chemical	Loose smut of barley
J. Sock,[2] M.Sc. Dr.Sc.Agr.	Molecular biology of cereal rusts
D. Tuma, M.Sc.	Cereal mycology
L. Wong, Ph.D. Western Grains Research Foundation	Fusarium head blight
H. Zhang Visiting scientist, Northwest Plateau Institute of Biology, Academia, Sinica People's Republic of China July 1987–July 1988	Wheat breeding and quality

Graduate students

S. Fox, B.Sc.A.	Oat breeding
S. German	Rust pathology
B. Innes, B.Sc., M.Sc.	Wheat cytogenetics
J. Leferink, B.S.A.(Eng)	Economic entomology
X. Chen	Cereal rusts

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[1] Seconded from Libraries Division, Finance and Administration Branch.
[2] Funded under the Canada–Manitoba Agri-food Subagreement (ERDA).
[3] Appointed 1 March 1988.
[4] Seconded to Research Coordination Directorate, Ottawa, October 1988.
[5] Appointed 6 September 1988.
[6] Appointed 5 December 1988 as a biologist under the Canada–Manitoba Agri-food Subagreement (ERDA).
[7] Appointed 18 April 1988.

INTRODUCTION

Research programs at the Winnipeg Research Station focus on three main areas of responsibility: the development of improved cultivars of cereals specifically adapted to the rust area of the eastern prairies; research on the integrated control of insect pests of field crops; and research on the protection of stored cereals, oilseeds, and their products. In each of these areas, interdisciplinary teams of scientists are pursuing both mission-oriented and basic research in support of the department's objectives of sustainable agriculture, food quality and safety, and market competitiveness.

The development of improved cereal cultivars requires the close collaboration of breeders, geneticists, cytogeneticists, plant pathologists, cereal chemists, and biotechnologists. Indeed, during the past year, our first application of biotechnology to cereal breeding programs has demonstrated how specific monoclonal antibodies can be used to rapidly screen breeders' lines for superior end-use quality and for resistance to barley yellow dwarf virus. The importance of maintaining such strong interdisciplinary teams in cereal cultivar development was also apparent when a rapid increase was detected in the incidence of new races of oat crown rust that can attack current resistant cultivars.

Research on the integrated control of field crop insects, particularly those that attack canola and the various special crops grown in southern Manitoba, includes the biology and ecology of pest species, the evaluation of biological and chemical control measures, the assessment of economic damage, and the development of integrated management systems. We are increasingly focusing on opportunities to use host resistance to reduce losses from crop pests. In this regard, field research over the past 2 years has demonstrated that some currently recommended sunflower hybrids have a useful level of resistance to the sunflower midge, which has caused serious losses in southern Manitoba.

Our research on the storage and protection of cereals, oilseeds, and their products is national in scope and involves close cooperation with the Canadian Grain Commission, the Food Production and Inspection Branch of Agriculture Canada, and the grain industry. Particular emphasis is placed on understanding the ecology of organisms that infest stored grain, the development of safe storage guidelines, nonpesticide measures to control infestations, and the microbiological and environmental factors influencing the occurrence of mycotoxins. The importance of our mycotoxin research was clearly illustrated in 1988 with the detection of ochratoxin A in the blood of slaughterhouse hogs in collaborative studies with the Department of Animal Science, University of Manitoba.

The station's two-row malting barley breeding program was transferred to the Brandon Research Station in preparation for Dr. D.R. Metcalfe's retirement in 1989 and in keeping with the Research Branch's policy of consolidation of programs. The Winnipeg Station will, however, continue to be responsible for research on malting quality and disease resistance in support of the breeding program. Following a long and productive career as leader of the hard red spring wheat breeding program, Dr. A.B. Campbell retired with an unprecedented record of nine cultivars released during his career. His position was filled by the transfer of Dr. T.F. Townley-Smith from the Swift Current Research Station. Other new staff members include Dr. P. Fields, postharvest insect physiologist, and Mr. I. Wise, pesticide evaluation.

The following short reports of recent research are indicative of the types of studies under way. Further information can be found in our annual *Research Update* or in the publications listed here, copies of which can be obtained by writing to individual scientists or to the Research Station, Research Branch, Agriculture Canada, 195 Dafoe Road, Winnipeg, Man. R3T 2M9; Tel. (204) 269-2100.

T.G. Atkinson
Director

BREEDING, GENETICS, AND CYTOGENETICS

Barley

Two cultivars recently released from the Winnipeg Station are being well accepted by Manitoba producers. Ellice, a two-row malting barley released in 1987, and Norbert, a two-row feed barley registered in 1980, were planted on a total of 74 700 ha (12.4% of the total area sown to barley in Manitoba, the area of adaptation of these two cultivars) in 1988. The faster malting rate of Ellice is enhancing its acceptance by maltsters.

Resistance to stem rust in North American barleys has depended entirely on the T gene for over 70 years. Despite the stability of the T gene, the dependence on one gene and the identification of stem rust isolates virulent on it indicated the need for additional sources of resistance. A new dominant gene conferring resistance to stem rust was identified in research on germ plasm isolation and evaluation, partly funded by the Canada–Manitoba Economic Regional Development Agreement. Genetic studies indicate that this gene, found in accession PI382313 from the United States Department of Agriculture Wiebe collection, provides a level of field resistance equivalent to that of the T gene.

It has been known for many years that the Yd2 gene confers a high level of resistance to barley yellow dwarf (BYD) virus in barley. Only recently, however, has this gene been incorporated into agronomically desirable barley lines suitable for use in the breeding program. Such BYD-resistant lines, along with other barley populations at various stages of development, were transferred in 1988 to staff at the Brandon Research Station as part of the consolidation of the Manitoba barley breeding programs. The Winnipeg Research Station will continue to be responsible for research on barley diseases and malting quality and will support the Brandon breeding programs in these areas.

During the year the efficiency of the barley malting quality screening program was greatly improved with the installation of a custom-built, 100-sample capacity malting unit, the basic design of which was conceived by Winnipeg Research Station personnel.

Hard red spring wheat

Hard red spring wheat cultivars from the Winnipeg Station continued to have widespread acceptance across the prairies. Just over 30% (9.1 million ha) of the total area sown to hard red spring wheat was planted to Winnipeg cultivars. Katepwa, at 41% of the prairie bread wheat area, has clearly replaced Neepawa as the dominant cultivar, a position it held for 13 years.

A number of important findings were made in 1988 concerning the identification, transfer, and control of genes providing resistance to the rusts. An inheritance study to determine the number of wheat leaf rust (Lr) resistance genes in the Canadian cultivar Kenyon [(Neepawa) 5× (Buck Manantial)] showed that it carries genes *Lr13* and *Lr16*. The donor cultivar, Buck Manantial, has *Lr3*, *Lr13*, *Lr16*, *Lr17*, as well as a gene for adult plant leaf rust resistance. A previously unidentified gene for leaf rust resistance was identified in two accessions, V336 and V618, of the A.E. Watkins wheat collection. This gene is dominant and gives a fleck (resistant) infection type to all isolates of leaf rust. Seedling leaf rust resistance transferred to Marquis from RL5347 (*Aegilops speltoides* Tausch × *Triticum monococcum* L.) was shown to be determined by a dominant gene that confers good resistance to all leaf rust cultures tested. The baking quality of the resistant stock was equal to Marquis, indicating that no deleterious characteristics were transferred from *A. speltoides*. This new gene should be a useful addition to the pool of resistance available to breeders.

The transfer of leaf rust resistance genes from diploid and tetraploid wheats to hexaploid wheats is difficult. In a study to test the hypothesis that *Lr34* may facilitate such transfers, a hexaploid line with *Lr34* was used as a recurrent parent to transfer leaf rust resistance from diploid and tetraploid species. After three backcrosses, leaf rust resistance was successfully transferred from tetraploid to hexaploid wheat but not from diploid to hexaploid wheat. Previous studies on the inheritance of stem rust resistance in RL5713 (derived from *A. squarrosa* L.) were indecisive. F_2 and F_3 data from crosses with Marquis (susceptible) indicated two genes were involved, whereas reciprocal backcrosses showed only one gene. The backcross data also suggested that male gametes bearing the resistance gene were preferentially transmitted. Additional resistant lines, selected from various backcross populations, have been identified that result in resistant-to-susceptible segregation ratios of 3:1 when used as parents in hybrid

populations. The resistance of this single dominant gene is effective against all cultures of stem rust tested.

The sprouting resistant cultivar Columbus was found to contain four gliadin protein bands that are present in RL4137, the source of the sprouting resistance in Columbus but not in Neepawa. Polyacrylamide gel electrophoresis (PAGE) of 92 random lines of RL4137 × Neepawa showed that two of the bands may be loosely associated with dormancy. There was no association of high molecular weight glutenin subunits with dormancy.

Canada prairie spring wheat

The selection criteria of the breeding program for prairie spring wheats, supported in part by the Canada–Manitoba Economic Regional Development Agreement, continued to emphasize high yield, early maturity, and resistance to sprouting, tan spot, and rust. Because 1988 was the hottest summer ever recorded in Winnipeg, as well as one of the driest, selection for heat and drought tolerance was possible. Three promising lines were entered in the high-yield co-op wheat test. Results from the eastern prairie high-yield B wheat test indicated several of the Winnipeg lines outyielded all the checks and are promising for a number of other attributes, including earliness and sprouting resistance.

Individual lines of three medium-hard prairie spring wheats were analyzed for kernel hardness. HY320 and HY355 were composed of hard and soft lines: 38% and 74% hard lines, respectively. The Canada prairie spring cultivar Oslo consisted of a single hardness category and could be more accurately classified as a hard red spring wheat.

Durum wheat

Sixty percent (75 000 ha) of the area seeded to durum in Manitoba and 20% of the prairie durum area was planted to cultivars released from the Winnipeg Research Station. The durum wheat breeding objectives continued to emphasize early maturity, moderate height, lodging resistance, rust resistance, and head and kernel type. Sixteen single and three-way crosses were made; extensive use was made of the intermediate height parent Sceptre and semidwarf lines, with the objective of improving lodging resistance. There were three lines in the 1988 durum co-op test.

A genetic study showed that the cultivars Coulter and Medora each carry three genes for seedling resistance to races *C10* and *C17* of stem rust: one gene conditions resistance to *C10*, one to *C17*, and one to both races. Based on rust reactions and the ancestry of these cultivars, it is postulated that the genes are *Sr7a*, *Sr9e*, and *Sr13*. Crosses to confirm the presence of these genes have been made. These three genes account for the seedling resistance of these cultivars to over 20 races. This knowledge provides the basis for incorporating additional genes for stem rust resistance.

The use of monoclonal antibodies (MABs) specific for gliadin band 45 to select for gluten strength was investigated using lines from the durum wheat program. High correlations were obtained between the enzyme-linked immunosorbent assay (ELISA) test for binding of MABs and sodium dodecyl sulfate (SDS)-sedimentation volume, gluten elasticity, and presence of gliadin band 45. The results indicate that this MAB has potential as a rapid screening test for high gluten strength using small samples of breeders' lines.

Oats

Essentially, 100% (215 500 ha) of the total area seeded to oats in Manitoba and 34% of the prairie oat area was planted to cultivars released from the Winnipeg Research Station. The oat-breeding program continued to emphasize high yield combined with a high-quality kernel and resistance to crown rust, stem rust, smut, and barley yellow dwarf. Thirty-one crosses and five backcrosses were made to develop superior oat cultivars, and selections were made among 11 000 F_4–F_8 lines. Eight high-yielding, disease-resistant lines were tested in the 1988 western co-op oat test.

An allelism study to identify a gene found in IB3056 that gives broad-spectrum resistance to most races of crown rust was concluded. Segregation ratios within seven F_2 populations involving this gene and known crown rust resistance genes indicated that it is allelic to or the same gene as *Pc68*.

CEREAL DISEASES

Our research in cereal pathology involves basic studies in genetics, biochemistry, biotechnology, ultrastructure, pathogen virulence, and epidemiology, as well as control of

diseases of wheat, oats, and barley. This information is used in support of the development of disease-resistant cereal cultivars to minimize yield losses, improve grain quality, minimize pesticide input, and avoid contamination of the environment.

Cereal rusts

Incidence. The rust diseases were not a serious threat to any of the cereals in 1988 as a result of the exceptionally warm and dry conditions. Low incidences of the stem rusts of wheat and oats and of oat crown rust occurred in Manitoba, and only trace amounts were found in eastern Saskatchewan. Wheat leaf rust was more widespread and may have caused minor losses in some late-sown fields of Neepawa and Katepwa wheat.

Analysis of virulence. A new system for identifying and naming races of wheat stem rust was introduced in 1988. The new system uses an internationally coded procedure. Using this system, eight races of wheat stem rust were identified in 1988. It is not possible to correlate these completely with the old C system, although the culture previously identified as *C53* was still the predominant race. No new virulence combinations were found that threatened the currently used sources of stem rust resistance. Races of wheat leaf rust were also identified using a new international system of race nomenclature. From across Canada, 16 races were identified from 347 isolates. From the prairie region, the level of virulence on the resistance genes *Lr24* and *Lr26* has increased rapidly since 1987.

A wider range than usual of oat stem rust races was found. From collections made across Canada, 25 races were identified, the majority of which were from Manitoba. In previous years a single race, *Na27*, dominated the prairie oat stem rust population. While still the dominant race in 1988, it was reduced to 60% of the rust population. From across Canada, 43 virulence combinations of oat crown rust were identified. In the Ontario rust population, the frequency of virulence on lines with gene *Pc39* increased to over 90% of isolates, sufficient to threaten any cultivars utilizing gene *Pc39* for resistance. In addition, isolates were found in Ontario with combined virulence to genes *Pc38* and *Pc39*, which are the main sources of crown rust resistance in oat cultivars developed for Manitoba.

Sources and transfer of rust resistance. Separate genes for resistance to oat crown and oat stem rusts were isolated from a single accession of *Avena sterilis* L. obtained from Spain. The gene for stem rust resistance is a new, simply inherited gene effective only in the adult plant stage. The gene for crown rust resistance was shown to be the same as a previously isolated gene, *Pc68*.

Cereal smuts

Occurrence and distribution. Heat and drought stress generally reduced the levels of cereal smut infections in Manitoba, Saskatchewan, and Alberta in 1988. Smut was detected in 75% of 271 barley fields surveyed. Of these, 62% were loose smut, 18% false loose smut, and 25% covered smut. The mean incidence of infection was 0.17%. In hard red spring wheat, 14% of fields were infected with loose smut, with a mean infection level of 0.01% and a maximum of 0.2%. In durum wheat, 47% of fields were infected, with a mean infection level of 0.18% and a maximum of 2%. In oats, 13% of fields were infected by either loose or covered smut, with mean and maximum infection levels of 0.04% and 1.0%, respectively.

Pathogenicity. Field collections of loose smut obtained from wheat from Canada, the United States, and the USSR showed the occurrence of three new races, but they do not threaten current resistant cultivars. There were no new virulent races of oat smuts. Species of *Ustilago* were collected from *Aegilops* and other grasses related to wheat in Uzbekistan, USSR. Host specificity was found at the genus level in *Avena* by six strains of each of *Ustilago avenae* (Pers.) Rostr. and *U. kolleri* Wille.

General pathology

Barley. Heat and drought stress kept most foliar diseases (mainly net blotch and spot blotch) at low levels in 1988. In northwestern Manitoba, where rainfall was higher, normal or above normal disease levels occurred. Tests of adult plant reactions to the net and spot blotch diseases caused by *Pyrenophora teres* (Died.) Drechs. showed a distinction in reactions between two-row and six-row barleys which had not previously been identified. Nine major pathotype groups of *P. teres* were identified using nine different barley lines. The variability found in western Canada was much greater than previously recognized.

Research Station, Winnipeg, Man.

Wheat. Foliar diseases other than rusts were not significant in wheat fields in 1988. However, in an inoculated nursery trial at Glenlea, a 14% increase in yield in Katepwa wheat was obtained when *Septoria* and tan spot were controlled with fungicides, demonstrating the desirability of developing cultivars with resistance to these foliar pathogens. A 9% yield increase with the partly resistant cultivar Erik, although not significant, also suggests the value of such resistance. Some hard red spring, prairie spring, and durum wheats were compared for reaction to spot blotch caused by *Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dastur. The hard red spring wheats Katepwa and Neepawa were unexpectedly susceptible, developing lesions that could be confused with those of tan spot. Progeny of crosses to improve tan spot resistance in hard red spring and durum wheats were tested, and some showed promising resistance. *Fusarium* head blight was at insignificant levels in Manitoba in 1988 because of the drought conditions. Preliminary screening tests indicated the occurrence of resistance to *Fusarium graminearum* (Schwabe) Snyd. & Hans. in some exotic wheat lines.

Virology

Barley yellow dwarf virus (BYDV). The incidence of BYDV was sporadic in 1988. Although the vector aphids were detected early, the warm and dry conditions limited aphid multiplication. These conditions may also have confounded identification of plants infected with BYDV. Some barley fields in eastern Manitoba undoubtedly sustained damage due to BYDV. High levels of resistance to BYDV in barley lines with the *Yd2* gene were demonstrated by five different parameters: seed yield, harvest index, aboveground biomass, root mass, and ELISA assay. It was shown that a rapid virus assay (ELISA) can be used to screen barley lines for BYDV resistance at early stages of growth. This method complemented other data, indicating that the *Yd2* gene behaves as a single recessive character.

Other viruses. Flame chlorosis was confirmed as a new and spreading disease, mainly of barley. It was found in a number of new locations and may have been detected in a few wheat fields. In two fields of barley, the incidence of affected plants was near 20%, indicating economic losses. A soil-inhabiting fungus, *Polymyxa graminis* Led., was associated with roots of affected plants. All transmission tests other than using soil from infested fields have failed, suggesting that *P. graminis* is a vector of flame chlorosis. Brome mosaic virus was detected in a single field of wheat near Minnedosa.

Molecular biology and biotechnology

Physical maps of linear plasmids of several *Tilletia* spp. were constructed using restriction enzymes and exonucleases. There was no homology to ribosomal genes or to any sequence in the total DNA of *Ustilago hordei* (Pers.) Lagerh. or *Puccinia graminis* Pers. f. sp. *tritici* Eriks & Henn. Interspecific variation in the restriction fragment length polymorphism of mitochondrial DNA from wheat, rye, and oat stem rusts was shown, although wheat and rye stem rusts shared homologous sequences, indicating their closer relationship. Multisegments of ds-RNA from rust fungal mitochondria contained a unique 5.0-kilobase segment, which appears to be a molecular marker for the Uredinales. Analysis of intercellular washing fluids (IWF) from rust-infected wheat leaves has demonstrated the occurrence of high molecular weight ConA-binding glycoproteins. Immunocytochemical methods confirmed that certain proteins in IWF originate in the fungus. Some of these fungal proteins were localized in the extramural substance of intercellular hyphal cells by utilizing specific antibody probes.

Specificity of monoclonal antibodies (MABs) against gliadin band 45 from wheat was demonstrated and was verified as a useful test to screen for pasta quality in durum wheat. It was also shown that the same MAB could be used to test for the wheat–rye translocations on chromosome 1B since the gene controlling band 45 gliadin also occurs on the same arm of that chromosome.

Electron microscopy

The occurrence and form of extramural coating substances on intercellular hyphae of wheat stem rust were elucidated using cryopreservation and cytochemical techniques. The extramural substances appear to have unique roles in the rust–host interactions. A variety of gold-labeled lectin probes were used to determine the glycocomposition of fungal

and host walls and of the extrahaustorial matrix in rust–host interactions. A new probe, arabinogalactan protein, specific for β-linked bound sugars, was described for the first time. Intense ATPase, acid phosphatase, and thiamine pyrophosphatase activities were localized in the oat–crown rust interface. Scanning electron microscopy was used to assay spore spines in a study of the inheritance of echinula-tion in progeny of *Ustilago nigra* × *U. hordei*.

CROP PROTECTION

Research on insect pests of oilseed, cereal, vegetable, and special crops emphasizes aspects of their biology and control leading toward better prediction of infestations, crop protection, and the reduction of pest populations. These programs are supported by research on sampling techniques, survival, development, phenology, host selection, induction and termination of diapause, overwintering strategies, reproductive biology, and the biochemical bases of neurotransmission.

Monitoring and prediction

Sex attractant trap catches of male specimens of the bertha armyworm, *Mamestra configurata* Walker, continued to be below the threshold for predicting a larval outbreak, and larval densities were less than 2.1/m^2. Part of the population failed to enter diapause because of the hot summer and emerged as adults in August and early September. The number of moths of this flight captured in traps was about 25% of the first flight, and because the adults flying in August would leave no progeny, no increase in population should occur in 1989.

As part of a project funded under the Canada–Manitoba Economic Regional Development Agreement, the distribution and damage caused by selected insect pests of field crops in Manitoba were determined. The incidence of damage to corn caused by the European corn borer, *Ostrinia nubilalis* (Hübner), was significantly lower than in 1987. An average of 2.8 broken stalks per 100 plants, 1.0 larva per broken stalk, and 0.2 larva per plant with unbroken stalks occurred. Sex attractant traps were found to be more accurate than light traps in predicting when and where damage to corn is likely to occur. Damage caused by the sunflower midge, *Continaria schulzi* (Gagne), was also low in 1988. An average of 15.7% of canola seeds in pod samples taken throughout Manitoba were destroyed, apparently by the feeding of *Lygus* bugs. *Lygus lineolaris* (Palisot de Beauvois) and *L. borealis* (Kelton) were the most abundant *Lygus* spp. collected in canola fields. Populations of pea aphids, *Acyrthosiphon pisum* (Harris), were also relatively low in 1988; only 25% of the fields sampled had aphid levels above the economic threshold.

Damage assessment

Controlled field experiments showed that feeding by the redbacked cutworm, *Euxoa ochrogaster* (Guenée), on flax caused plant losses that increased with larval density until all plants were destroyed at 32 larvae per square metre. Yield per plant increased in response to decreased plant densities, but the increase did not compensate for plant loss.

Biological control

Collections of parasitized pea aphids from alfalfa fields in the Red River Valley were small, and no specimens of the recently introduced *Aphidius smithi* Sharma & Subba Rao were recovered. However, *Coccinella septempunctata* (L.), an aphid predator introduced to eastern North America from Europe, was found for the first time in Manitoba in alfalfa fields near Winnipeg.

Field-collected flea beetles (*Phyllotreta* spp.) exhibited feeding preferences for cruciferous host plants in laboratory tests. Choice tests using the cotyledon stage of *Brassica oleracea* L. (broccoli), *B. campestris* L. (cultivar Tobin), *B. napus* L. (cultivar Westar), *B. nigra* (L.) Koch, *B. juncea* (L.) Czern. (cultivar Cutlass), *Raphanus sativus* L., *Sinapis alba* L., and *S. arvensis* L. showed that *S. arvensis* and *S. alba* were damaged the least and *R. sativus* the most. In nonchoice tests, *B. oleracea* had the highest level of damage; the two species of *Sinapis* had low levels of damage, but the differences were not significantly different from the other species tested. Field studies using potted plants also revealed that *R. sativus* was the most attractive to flea beetles of all the crucifers tested.

Despite low populations of sunflower midge, the occurrence of resistance and susceptibility among registered sunflower hybrids was evident in field tests, confirming 1987 tests and indicating that host resistance provides a practical control measure.

Research Station, Winnipeg, Man.

Insecticides

The effectiveness of bacterial insecticides based on *Bacillus thuringiensis* var. *tenebrionis* varied with formulation in tests against the Colorado potato beetle, *Leptinotarsa decemlineata* (Say).

Nine strains or species of entomopathogenic nematodes have been bioassayed against six species of cutworms. Greenhouse tests showed that some of these nematodes were as effective in protecting flax seedlings from damage by the redbacked cutworm and the black cutworm, *Agrotis ipsilon* (Hufnagel), as the recommended insecticide Lorsban. The nematodes were less effective in field tests, but nevertheless are potential alternatives to chemical insecticides for cutworm control.

Biology and physiology

Exposures to temperatures below −15°C for 3–6 h did not freeze diapausing pupae of the bertha armyworm but significantly reduced survival to adult emergence. Similar treatment did not reduce the survival of diapausing pupae of the cabbage maggot, *Delia radicum* (L.).

A field study in 1987 and 1988 showed that the flight period of the redbacked cutworm in southern Manitoba extended from late June to mid September. Most of the mating and egg laying occurred during the peak of the flight period, which was from mid July to mid August.

PROTECTION OF STORED PRODUCTS

Research on the biology and control of pests in stored cereals and oilseeds and their by-products emphasizes the interaction of insects, mites, and microorganisms in a dynamic storage environment. The program includes studies of grain storage management during long-term storage; survey, prediction, and control of microflora and mycotoxins in stored cereals and oilseeds; identification and quantification of insects and mites in stored products; influence of attractants and feeding stimuli on insect behavior; and control of insects and mites by environmental, physical, and chemical means.

Storage ecology

With funding support from the Canola Council of Canada, the conditions for storing canola meal with negligible quality loss were determined. During 1 year of storage, little quality loss occurred at 30°C and 7% moisture content (MC), 25°C and 9.5% MC, or 20°C and 12% MC. Fifteen species of stored-product insects and mites were exposed to canola meal, but only *Tribolium* species successfully multiplied on it.

Population fluctuation and spatial distribution patterns of five species of *Pscoptera* (book lice) were determined during 1959–1979 in 12 cereal and oilseed bulks, each stored for 2–6 years in granaries typical of those used on Manitoba farms. *Lepinotus reticulatus* Enderlein, *Liposcelis bostrychophilus* Badonnel, and other *Liposcelis* spp. naturally infested wheat, oats, and barley initially stored at 10.3–14.0% MC and canola at 6.3–11.6% MC. Generally, the psocids were sparsely distributed and occurred in all parts of the granaries throughout the year, but their frequency of occurrence and number per sample increased during late summer and autumn. Only one serious outbreak involving *L. reticulatus* was observed during the 20 years.

Microflora and mycotoxins

The mycotoxins ochratoxin A and citrinin were developed in 11-kg parcels of amber durum wheat at 15 and 19% initial MC and exposed to simulated bulk storage in a Manitoba granary for 60 weeks. Ochratoxin A reached maximum levels of 11.8 and 0.11 ppm at 19 and 15% initial MC, respectively, during weeks 44–48; citrinin reached levels of 80.0 and 0.65 ppm at these moisture levels, respectively, during the same period.

Twelve hundred blood samples obtained in 1986 from slaughterhouse hogs in western Canada were assayed for ochratoxin A, because it is a potential contaminant in the feed system. High performance liquid chromatography analysis demonstrated that 3.6 and 4.2% of the blood samples collected in February and March (n = 194) and May, June, and July (n = 1006), respectively, had ochratoxin concentrations that exceeded 20 ng/mL. In general, the percentage of samples that had concentrations of greater than 10, 20, 50, 100, and 200 ng/mL serum were 11.3, 4.1, 1.25, 0.42, and 0.08%, respectively. These blood serum ochratoxin concentrations

are a good indicator of tissue concentrations, particularly in the liver and kidney.

Hard red spring wheat, stored at 20 and 25% moisture content for 10 months during 1985–1986, was monitored for biotic and abiotic variables in 10 bins in Winnipeg, Man. The major odor volatiles identified were 3-methyl-1-butanol, 3-octanone, and 1-octen-3-ol. The production of these volatiles was correlated with microfloral infection. Ventilation, used for cooling and drying of grain, disrupted microfloral growth and thus the production of volatiles. The highest levels of 3-methyl-1-butanol occurred in 25% MC wheat infected with bacteria, *Penicillium* spp., and *Fusarium* spp. Detection of odor volatiles provides an early-warning system for monitoring grain spoilage.

Biology

Oviposition and larval development of the red flour beetle, *Tribolium castaneum* (Herbst), and the rusty grain beetle, *Cryptolestes ferrugineus* (Stephens), were used as criteria of the nutritional value of 28 ground or 29 ball-milled cultivars of two-row and six-row barley, oats, triticale, and durum and common wheat. Durum wheat cultivars were consistently the most nutritious, whereas oats were the least nutritious for these storage insects.

Control

The amount of residue of the insecticides chlorpyrifos-methyl, pirimiphos-methyl, and malathion, applied separately at 3–6 ppm, was not significantly different on either freshly harvested or previously stored wheat after 1 year. Thus, application rates of these insecticides used on new and old wheat should be similar.

Adults and larvae of the merchant grain beetle, *Oryzaephilus mercator* (Fauvel), and the confused flour beetle, *T. confusum* Jacquelin du Val, were exposed to silica aerogel glued to wood surfaces. Mortality was directly related to duration of exposure to the silica aerogel and the length of time between such exposure and availability of food. *O. mercator* was killed with 15 s of exposure and 2 h of starvation, but *T. confusum* needed 6 h of exposure. Larvae were as susceptible as adults. Type and quantity of food also affected insect survival. The use of silica aerogel as a means of controlling insect pests of stored food in dwellings has been submitted for patent protection.

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Departure

Z. Mir, B.Sc., M.Sc., Ph.D. Transferred to Kamloops Research Station, April 1988	Ruminant nutrition

INTRODUCTION

The Melfort Research Station was established in 1935 to serve the needs of crop and livestock producers in the Aspen Parkbelt of northeastern Saskatchewan, an area comprising 10% of Canada's improved agricultural land. It is well suited to the production of a wide range of agricultural crops and livestock. The station comprises 370 ha on a productive silty-clay loam and operates another 390 ha of bushland pasture project on a Gray wooded soil. The station's nine scientists are involved in interdisciplinary research aimed at improving the efficiency of crop and livestock production and the maintenance of soil productivity. Many cooperative research projects are undertaken with the province, the agricultural industry, and producer groups, whose support is appreciated.

During the year Dr. Z. Mir transferred to Kamloops and Dr. Alan Moulin, a soils specialist, was hired to work on soils management and conservation.

The station publishes *Research Highlights* annually; that publication and any other information relating to our work can be obtained by writing to us at the Research Station, Research Branch, Box 1240, Melfort, Sask. S0E 1A0; Tel. (306) 752-2776.

S.E. Beacom
Director

CROP PRODUCTION

Winter wheat seeding methods. A double-disc press drill, a hoe drill, and an air-seeder were used to seed winter wheat into standing stubble and a prepared seedbed from 1985 to 1987. Nitrogen fertilizer was broadcast at 0, 50, 100, and 150 kg/ha in the spring following seeding. Seeding implement had no effect on yield. In the first year, crops grown with and without prepared seedbed had nearly equal yields. In the second year, the crop on the prepared seedbed yielded nearly double that on standing stubble. However, a severe volunteer barley problem was partly controlled by the seedbed preparation. In the third year, seedbed preparation reduced yield by 25% when the volunteer crop was controlled, probably because trapped snow and available spring moisture were reduced. Nitrogen fertilizer increased the mean yield from 1110 kg/ha to 1270 and 1300 kg/ha with N at 50 and 100 kg/ha, respectively. When weeds and volunteer crops are adequately controlled, seeding winter wheat into standing stubble is recommended, particularly in a dry spring. Any drill that can get good seed placement without plugging will produce acceptable results with winter wheat.

Direct drilling into barley stubble. Two seedbed preparation systems were compared for seeding cereal, oilseed, and pulse crops into barley residue on light-, medium-heavy-, and heavy-textured soils in northeastern Saskatchewan. Seedbed preparation systems consisted of either direct drilling into standing stubble or drilling into a seedbed prepared in the spring after the stubble had been left standing over the winter to trap snow. Data covering an average of 9 station-years show that with adequate preseeding weed control, the direct drilling of fababean (*Vicia faba* L.), field pea (*Pisum sativum* L.), lentil (*Lens culinaris*), barley (*Hordeum vulgare* L.), and wheat (*Triticum aestivum* L.) gave yield increases of 6, 14, 24, 4, and 12%, respectively. Similarly, data from another experiment, covering an average of 7 station-years, show yield increases with direct drilling of 16, 15, 5, 11, and 9% for *Brassica campestris* L., *Brassica napus* L., flax (*Linum usitatissimum*), barley, and wheat, respectively. Lower yields associated with preseeding tillage were probably due to drying out of the seedbed.

Phosphorus fertilizer placement. The placement of N and P fertilizer in the soil relative to the position of the seed can markedly affect the efficiency of fertilizer use. The effect of deep banding (DB) P fertilizer at four different rates (P at 0, 10, 20, and 30 kg/ha with N applied at 75 kg/ha) was compared with seed placement (SD) and with one-half seed placed, one-half deep-banded (SDDB) in a 6-year rotation consisting of canola, four crops of wheat, and then canola grown on Melfort silty clay soil. In the first year of the experiment, SD of the

P fertilizer resulted in a significantly higher yield of canola (cultivar Regent) than DB (1.01 versus 0.88 t/ha). In the last year of the experiment, canola yields were not significantly different between SD and DB (1.87 versus 1.83 t/ha). There was no significant difference in wheat yields between SD and DB (2.97 versus 2.95 t/ha) over the 4 years. With increasing amounts of P in the soil over the period of the test, the method of fertilizer application became less significant.

Crop diseases. Disease surveys on crops grown in northeastern Saskatchewan have been carried out over the past 2 years. The dry spring of 1988, when compared with 1987, probably reduced some diseases. Pasmo of flax was found only in trace amounts in 1988, although it was a major disease in 1987. Wheat surveys showed lower levels of foliar disease but slightly higher root rot in 1988. All barley diseases except net blotch were at lower levels, and the spot form of net blotch was the major disease in 1988. Canola blackleg was severe, but other diseases of canola were reduced. Alfalfa foliar diseases were at low levels as was snow mold of forage legumes, grasses, and winter cereals in the spring. Mycosphaerella blight of pea appeared late in the season and did not attain high levels. Powdery mildew was the most severe disease of pea this year.

Weed control. Field peas, lentils, fababeans, and annual vetch exhibited greater tolerance to preemergence versus postemergence applications of imazethapyr with active ingredient (a.i.) tested at 50–200 g/ha. Despite delays in pod development, yield increases for peas, beans, and vetch were, however, higher with postemergence applications because of superior control of stinkweed. A postemergence application with a.i. at 100 g/ha resulted in 2520, 1660, 1610, and 1110 kg/ha of peas, beans, vetch, and lentils, respectively, which were 132, 134, 183, and 70% of the respective untreated pulses.

Weed control in forage crops. The long-term effects of postemergence herbicide treatments applied at the seedling stage in 1985 were assessed on productivity of forage grasses in 1987. The graminicides sethoxydim and fenoxaprop-ethyl, which severely damaged the grasses in the establishment stage, continued to depress yields. However, selectivity of fenoxaprop-ethyl (with a.i. at 0.18 kg/ha) improved considerably when tank-mixed with bromoxynil, because dry-matter yields of timothy, smooth bromegrass, and meadow brome increased 27, 49, and 79%, respectively. The highest yields of 5440, 4290, 5500, and 4200 kg/ha, respectively, for smooth bromegrass, meadow bromegrass, crested wheatgrass, and timothy were associated with combined application of diclofop-methyl + bromoxynil with a.i. at (0.7 + 0.3) kg/ha. Altai wild ryegrass, which proved to be the least competitive grass at the seedling stage, benefited most from the herbicide treatments. Metsulfuron tested with a.i. at 3 and 4.5 g/ha increased yields by 590 and 710%, respectively, compared with the untreated plots.

BEEF PRODUCTION, CROP UTILIZATION

Ruminant nutrition

Aureomycin (chlortetracycline) residues in beef. A study conducted in cooperation with the Health of Animals laboratory in Saskatoon revealed that supplementing a beef cattle finishing ration with 350 mg of aureomycin per head per day and withdrawing it 7 days before slaughter left no repeatably detectable residues of this antibiotic in the meat. Samples of muscle, kidney, liver, and perirenal fat were obtained from 14 control and 61 aureomycin-fed animals. Traces of aureomycin were detected in three samples of muscle, two of kidney, and two of liver, representing a total of six animals from those fed aureomycin. The levels were below the lowest limit for reliable measurement (100 ppb) and could not be replicated with additional subsamples from the same tissues. The use of aureomycin resulted in increased returns to labor of $36 per head over control cattle and $13 over cattle receiving monensin, a widely used feed supplement. Its use is thus of considerable economic significance to the beef industry, and if properly fed, of no concern to the consumer, as the level was well below the Canadian tolerance of 1 ppm in edible tissue.

Steer versus heifer carcasses. A review was conducted of carcass data from experiments over several years, in which a total of 339 steers and 379 heifers of comparable ages (grading A1 or A2, and of either Charolais × Simmental × Hereford or Charolais × Angus × Hereford breeding) were fed identical rations. The review showed that heifers reached finished condition at lighter weight

than steers (432 versus 556 kg), dressed out at 0.2 percentage units less (53.9 versus 54.1), and had slightly less backfat cover (0.84 versus 0.89 cm), smaller lean eye areas (76 versus 80 cm^2), and lower cutability (59.1 versus 59.3%). The difference in market price paid per unit weight for steer and heifer carcasses within acceptable weight ranges was far in excess of that justified by the slightly lower yield of the heifer carcasses (54% of heifer carcasses fell within the desirable weight range for steer carcasses).

Kochia silage. Kochia silage (KS) prepared from two cultivars of kochia, cut at two maturities and fed in a 50% combination with alfalfa silage (AS), was compared with a complete AS diet. Starch and soluble carbohydrate content and buffering capacity of fresh and ensiled samples of alfalfa were higher ($P < 0.05$) than those of either variety of kochia. Stage of maturity of kochia had no effect on those parameters. The pH of AS (4.7) and KS (5.0) was similar, but lactic acid content of AS was greater (3.7 versus 1.3%). Dietary nitrogen (N) (2.9–3.3%) and fiber component did not vary among diets, but ash content of the KS–AS diets was higher than the AS diet (12.1 versus 8.9%). Dry-matter (DM) intake of the AS diet was 2.3 kg/day and was higher ($P < 0.05$) than that for the KS–AS diets (1.8–1.9 kg/day). DM digestibility, N, and energy of the KS–AS diet were lower ($P < 0.05$) than for the AS diet and ranged from 59.7 to 64.9, 73.9 to 78.9, and 56.5 to 65.2%, respectively. Results indicate that kochia can be preserved as silage and used in sheep diets in combination with AS.

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INTRODUCTION

The program of the Regina Research Station focuses on the biology and control of weeds in cultivated crops and pastures and the chemistry of herbicides in the environment. The extensive use of herbicides in prairie agriculture has created a demand for scientific information on efficacy, crop tolerance, persistence in soil, and movement away from the intended target. Expertise on issues of herbicide safety is widely sought for collaborative research by Health and Welfare Canada, Environment Canada, National Hydrology Institute, Saskatchewan Research Council, and the pesticide industry. Integrated weed management and studies on biological control seek to develop means to reduce herbicide use. Great progress is being made on biological control of diffuse and spotted knapweed and on leafy spurge with the release of host-specific phytophagous insects. Development of a biological herbicide in collaboration with the firm Philom Bios is nearing completion.

Research programs at the Indian Head Experimental Farm include cereal and special crop agronomy. The emphasis is on crop management and weed control. Work includes maintenance of a plant breeding nursery for the south Saskatchewan wheat breeding project.

The Seed Increase Unit is responsible for increase, distribution, and maintenance of new cultivars of cereal, oilseed, and forage crops developed by Agriculture Canada and for a plant breeding nursery in winter at Brawley, Calif.

More detailed information on the station program may be obtained by directing enquiries to Research Station, Research Branch, Agriculture Canada, 5000 Wascana Parkway, P.O. Box 440, Regina, Sask. S4P 3A2; Tel. (306) 780-7400.

J. Dueck
Director

BIOLOGICAL CONTROL

Round-leaved mallow

An endemic fungus, *Colletotrichum gloeosporioides* f. sp. *malvae* (C.g.m.), causing anthracnose of round-leaved mallow, is being developed as a biological herbicide in cooperation with Philom Bios, a biotechnology firm, under the tradename BioMal. The regulatory registration agencies are concerned about environmental fate and persistence of all products, even when they are naturally occurring.

Survival and carry-over of the pathogen have been investigated to address regulatory requirements. C.g.m. was not found to persist in the soil. It was not reisolated from soil artificially inoculated with spores after 4 days at two locations with various soil properties, even when applied at 100 times the recommended rate. Similarly, C.g.m. persisted for only a short time in infected plant tissue that had been buried at seeding or tillage depth. Survival of C.g.m. in buried infected plant tissue declined rapidly within a few weeks of burial and was not detected 12 weeks after burial or after a winter. C.g.m. naturally overwinters in infected plant tissue left on the surface of the soil. Even after augmentation, less than 10% of the infected tissue remaining on the soil surface after the winter produced C.g.m. when cultured on artificial medium.

Carry-over was investigated in previously treated plots subjected to four different cultivation treatments. More carry-over than expected from the previous survival experiments was observed in the first year. Timely rains throughout the season coupled with a great amount of infected trash left on the soil surface may explain the high levels of carry-over and secondary infection. In the second year, drought conditions prevailed and much less carry-over was observed. In cultivation treatments with the least soil disturbance, more infected trash was present and disease development was more rapid. In general, disease development was much slower in carry-over plots than in plots sprayed with C.g.m.

Bladder campion

The flower- and leaf-feeding beetle *Cassida azurea* Fab. does not develop eggs while feeding on genera closely related to the target weed, including the one cogeneric native *Silene*

species that was tested. Larval feeding on six native campion species was 42% less than on bladder campion. Therefore, *C. azurea* is a safe and promising biological control agent for bladder campion.

Diffuse and spotted knapweed

The combination of the root boring beetle, *Sphenoptera jugoslavica*, and the seed head flies *Urophora affinis* and *U. quadrifasciata* has slowly but persistently depressed the diffuse knapweed stand at White Lake, B.C. There were 10.5 bolting knapweed plants per square metre, 6.2 rosettes per square metre, and an *S. jugoslavica* population of 7.4 beetles per square metre. This is the lowest knapweed population since the beetle release in 1976. Additional field releases were made in British Columbia on both knapweeds. Adapted *S jugoslavica* was supplied to the United States.

Seed production of spotted knapweed at Chase, B.C., with the two seed head flies and the seed head moth, *Metzneria paucipunctella*, has declined from around 40 000 seeds per square metre to 1660 seeds per square metre in 1988.

For moist sites the knapweed root moth, *Agapeta zoegana*, is well established at several locations in British Columbia. Strong colonies of the meisic root moth, *Pelochrista medullana*, and the root weevil, *Cyphocleonus achates*, were established so that field releases can be made in 1989.

A heavy infestation of the diffuse knapweed rust, *Puccinia jaceae* var. *diffusae*, was found in Oliver, B.C. This should provide a major boost to the control of this weed.

Leafy spurge

The root-feeding flea beetle *Aphthona nigriscutis* was introduced from Hungary in 1983. A rapid population increase was noticed in 1986 in both Alberta and Manitoba. By 1987 it had reduced spurge flowering and stem height, and by 1988 native vegetation started to return in the centre of the release area. The beetles are doing well on dry, well-drained slopes and poorly in swales. There have been 3 releases in British Columbia, 6 in Alberta, 20 in Saskatchewan, 28 in Manitoba, and 4 in Ontario. The fate of the Ontario colonies is uncertain, but most of those in western Canada are thriving. The main drawback of the beetle is that spread is only a few metres a year. Adapted stock from Cardston, Alta., was provided to the United States.

The shoot gall fly, *Bayeria capitigena*, obtained from Switzerland and Italy and released in 1987, survived the winter in Regina and completed two generations, despite a requirement for moist conditions. The leaf tying moth, *Lobesia euphorbiana*, released in 1983 with stock from Italy, now appears to be synchronized with the climate. It successfully completed four generations in a field cage in Regina in 1988. A release made in Brandon, Man., in 1988, emerged for a second generation at the end of August. One additional release was made in Manitoba and two in Saskatchewan.

The flea beetle *Aphthona czwalina* survived in a Regina field cage. A strong colony of *A. flava* is established on leafy spurge at Cardston, Alta., and another on cypress spurge in Ontario. Stock of *A. flava* was obtained from Inner Mongolia for release in Manitoba and Saskatchewan. A flourishing colony of *A. cyparissiae* is established at Maxim, Sask., on robust spurge growing on a lakeshore. This was used for secondary releases in Saskatchewan and provided adapted stock to the United States. To date, there have been two releases in Alberta, nine in Saskatchewan, five in Manitoba, and three in Ontario.

WEED ECOLOGY AND PHYSIOLOGY

Expert Committee on Weeds computerization and retrieval

Each year the research report of the Expert Committee on Weeds (western section) contains up to 1200 computerized and 300 non-computerized abstracts. A retrieval program, implemented in 1984, allowed limited access to the data base, which contains computerized abstracts from 1976 to the current year. This retrieval information has proved extremely valuable as a historical weed control record and, for the chemical industry, as a tool in the registration process.

In 1988 a pilot Electronic Data Input (ECW-EDI) floppy disk program was distributed to 13 weed researchers (five from Agriculture Canada and eight from industry) in western Canada. The main goal of developing ECW-EDI was to eliminate keypunching and other production charges and to reduce

duplication of data entry. The research report contained 120 abstracts submitted electronically, which constitutes 15% of the total computerized submissions. The 1989 research report will be produced using the ECW–EDI system, which can be distributed free of charge.

The data-base management system selected for the general rewriting of the computerization and retrieval system will facilitate the creation of a national weed control data base for ECW in the East and the West, as well as an in-depth retrieval program. This system will also accommodate all sections previously unable to "fit" the computerized format, such as forestry, adjuvants, and environmental chemistry, among others.

A major benefit to the system upgrading is that ECW in eastern Canada will be in a position to computerize their research report, using the program developed at the Regina Research Station. The new program is being written so that it can be coordinated with methods of reporting weed research in eastern Canada.

In the future, organizations will be able to transfer data from their in-house data bases into ECW format for electronic submission into the research report. The final phase of the upgrading includes the development of third-party access to the database for pesticide evaluators, people in industry, and other researchers. A continuing task will be to attempt to structure the new research report format to fill as many needs as possible.

In 1989 the new ECW production system (western section) will be run in-house at the Regina Research Station on a MicroVAX 3500, thus eliminating the problems associated with a remote job-entry site connected to the IBM computer in Ottawa as well as saving time and money.

Scentless chamomile

A four-year project on the integrated control of scentless chamomile, funded under the Canada–Saskatchewan Economic and Regional Development Agreement (ERDA), was completed.

A questionnaire sent to 39 594 farm households in the Black, Dark Gray, and Gray soils of Saskatchewan prompted a response by 3148 farmers. Thirty-four percent of the respondents said that scentless chamomile occurred on or adjacent to land they farmed, and 37% believed it was a serious problem or was most troublesome compared with other weeds. In total, 1889 locations of scentless chamomile were reported from 502 townships.

Scentless chamomile was ranked as one of the top five weed problems by over one-half of the 35 farmers with whom personal interviews were conducted in an area of Saskatchewan infested by the weed. The most commonly reported physical characteristics of scentless chamomile that made it a problem were the root system and the wiry, tough texture of the plant. The spread of scentless chamomile was related largely to agricultural activities such as movement of machinery, grain, and feed contaminated with seed.

The most common scentless chamomile habitats are roadsides, farm yards, farm buildings, fences, lanes, and power lines. It can have direct effects on agricultural production in low areas that are sometimes cropped, in cropped land, and around permanent sloughs that are never cropped. An estimate of the agriculturally most important habitat, the low areas of fields, constitutes 3% of the cultivated area in the Dark Brown soils, 1% in the Black soils, and 8% of the cultivated Dark Gray soils.

The germination of scentless chamomile seed, from eastern and western Canadian populations, was tested at various day–night temperature combinations. Most seed had initial viability of 90% or more. The optimum mean daily temperature was 17.5°C, but scentless chamomile germinated well at mean daily temperatures of 10°C–30°C. Below the optimum, germination of the western tetraploid populations was generally superior to that of the eastern diploids and was more rapid.

The spread of scentless chamomile has been partly blamed on the transportation of contaminated grain. Truck-box and bin samples were collected in an area infested with the weed. Samples of lentil, wheat, and mustard were found to contain mean densities of 31 000, 24 000, and 254 000 seeds per tonne of grain, respectively.

Summer annual scentless chamomile in a wet year, and the winter annual in a moderately moist year, strongly depressed the yield of spring wheat. Winter wheat yield was also affected, but to a much smaller degree.

Control with currently available methods is not easily accomplished. The spectrum of herbicides is limited, and bromoxynil, the herbicide most commonly used, must be applied while the plants are small seedlings. Cultivation can be effective if conditions are dry enough to minimize soil retention by the

weed's root system, but scentless chamomile occurs predominantly in the moister areas of the province.

Wild oats–barley competition

Rates of nitrate uptake were found to be significantly different among nine barley cultivars and five genetically pure lines of wild oats. As in a previous study in potassium uptake, rates of nitrate uptake were correlated with degree of seed dormancy of these wild oat lines, i.e., the more dormant lines (AN 51 and AN 474) had higher fluxes than the less dormant lines (SH 319 and SH 430). The genetic differences between crop and weed in endogenous seed nutrient levels (N, P, K), initial nitrate uptake rates, and growth in relation to nitrate supply should be considered in examining competitive effects such as weed–crop interactions.

Wild oats

A comparative study of the effect of mechanical injury on water uptake and germination in various pure lines of wild oats showed that the initial rate of water uptake by the embryo in the intact caryopses was inversely related to a genetically determined difference in their degree of dormancy. Mechanical injury of the seed coat resulted in a rapid increase in the water content of the embryo before emergence of the radicle. These results are consistent with the hypothesis that the supply of water to the embryo, as determined by the hydraulic conductivity of the enclosing tissues, plays a major role in the mechanism of dormancy in wild oats.

2,4-D tolerance and germination in lamb's-quarters

The environment in which plants grow can have a substantial influence on plants that are produced, both in physical appearance and germination. In a cropping situation, applied herbicides are an important aspect of the maternal environment for weeds. Herbicides often are applied at sublethal doses because of drift, the interception of spray by the crop canopy, increased herbicide tolerance of target species, or the deliberate cutting of rates to save money.

In order to investigate the effect of sublethal doses of 2,4-D on lamb's-quarters, plants from three sources were sprayed at the 4–6 leaf stage with rates of 2,4-D with active ingredient (a.i.) ranging from 0 to 0.6 kg/ha. The three sources had various levels of tolerance for 2,4-D. Surprisingly, the most tolerant source was from a field with no past history of herbicide application. With increasing 2,4-D rates, plants from all sources became weaker and less competitive, producing fewer seeds. At sublethal doses, lamb's-quarters plants were slower to flower and produce seeds. However, seeds that were produced by plants sprayed at higher rates were larger, germinated faster, and may have had a competitive edge over those from unsprayed plants.

Tolerance of winter wheat to phenoxy herbicides

The development of new winter wheat cultivars with increased winterhardiness has increased the winter survival potential of the crop. There has also been an agronomic change away from growing winter wheat on summerfallow to seeding into standing stubble as a means of maintaining a blanket of snow. These improvements have recently facilitated production of winter wheat outside the traditional areas. Winter annual and early spring annual broad-leaved weeds present a major problem to growers for production of winter wheat in these new regions.

Norstar winter wheat was sprayed in 1985–1986 and 1986–1987 to determine the effect of timing of application of the postemergent phenoxy herbicides 2,4-D and 4-chloro-2-methylphenoxyacetic acid (MCPA) on winter survival and crop tolerance of winter wheat, when applied in the fall compared with application in the spring.

In 1985–1986, fall treatments of both 2,4-D and MCPA increased the severity of lodging compared with spring treatments. Compared with spring applications, the fall treatment of 2,4-D at 850 g/ha significantly reduced the grain yield and kernel weight; all rates of MCPA reduced grain yield.

In the 1986–1987 crop year, fall applications of 2,4-D and MCPA did not affect winter survival of grain yield. At normal field rates, applications of 2,4-D and MCPA did not result in any injury to the winter wheat. Since the crop was 13 cm shorter in the second season, the serious lodging problems of the previous year were not a general concern, and the fall treatments did not cause lodging to be a serious problem.

Control of bud growth in perennial weeds

The persistence of perennial weeds is due mainly to their ability to regenerate from buds on their roots or rhizomes. The behavior of these buds determines both the weeds' capacity for regenerative growth and their susceptibility to herbicide and cultural treatments. A better understanding of the factors and physiological mechanisms regulating bud activity may lead to more effective methods of control.

A problem of particular significance is the mechanism by which the growth of the buds is inhibited by other parts of the plant. This phenomenon, known as correlative inhibition, is generally attributed to the inhibiting effect of specific hormonal factors. However, investigations have provided considerable evidence that the primary cause of inhibition is the inability of the buds to compete for water with the parent shoot. Additional support for this hypothesis was provided by a recent investigation involving the use of a specially designed strain-gauge transducer capable of measuring changes in bud growth with an accuracy of ± 1 µm.

In experiments with *Phaseolus vulgaris*, a species widely used for the study of correlative bud inhibition, bud growth measurements showed that both shoot decapitation and leaf excision triggered the almost instantaneous release of lateral buds from inhibition. This immediate growth response is attributed to the sudden increase in xylem water potential produced at the cut surfaces of the treated shoot and rapidly transmitted to the lateral buds. It was concluded that in the intact plant, the negative water potential generated by growth and transpiration limits the supply of water to the buds and thus plays a major role in the mechanism of bud inhibition.

Further investigations using the same technique showed that the buds on the root of milkweed (*Asclepias syriaca* L.) also respond immediately when released from inhibition by excision of the parent shoot. Similar experiments are now being conducted to determine the response to shoot excision of root and rhizome buds in other perennial weeds.

1986 Manitoba weed survey

The 1986 survey for weeds occurring in Manitoba cereal and oilseed crops indicated that no major shifts in weed species composition had occurred since the previous surveys in 1981. However, there was a 19% decrease in the relative importance of the grassy component of the weed community. Green foxtail and wild oats were the most abundant species. The decrease in the abundance of these grassy weeds was compensated for by an increase in the relative abundance of the annual broadleaved weeds that are usually controlled with 2,4-D, MCPA, or other herbicides used for broad-leaved weed control. Wild mustard, stinkweed, and dog mustard were examples of species in this component that were more frequent and were found at higher densities in 1986 than in 1981.

HERBICIDE BEHAVIOR IN THE ENVIRONMENT

Minor use program (herbicides) summary report

The minor use program for herbicides was initiated in 1976 to provide a means for the Canadian agricultural community to register needed additional pesticide uses for minor hectarage crops. In 1978 the Regina Research Station, in collaboration with the Pesticides Section, Food Production and Inspection Branch, developed new protocols for the registration of minor uses for herbicides along the lines already in place for other pesticides, stressing the importance of crop tolerance data and the role of the Expert Committee on Weeds.

During the 10-year period (1977–1986), over 140 submissions for minor herbicide uses were processed. Of these, 82 were submitted by provincial extension offices and stations, 38 by personnel in Research Branch and other agencies in Agriculture Canada, 13 by industry, 6 by grower groups, and 1 by a university.

Twenty-eight submissions were not accepted because they did not meet acceptance criteria. Thirty-five submissions required tolerance data, and some of these were generated in collaboration with interested agronomists. Forty-six submissions required residue data. Residue data have been generated for 31 of these submissions and another 8 are in the process of being generated. Of the 142 submissions during the period under review, 56 uses have been accepted and another 15 are at various stages of progress.

Research Branch, Agriculture Canada, as well as provincial and private laboratories were involved in generating residue data over

the past 10 years. Of these, the Regina Research Station laboratory was most active in generating these data (17 crops, 12 different herbicides). Kentville Research Station (blueberries), Harrow Research Station (cole crops), and the provincial laboratory at Guelph (peanuts) were used primarily for locally grown crops.

The success of the herbicide minor use program is evidenced by the individual and collaborative scientific publications generated over the years. Thirty-four research publications have been published; of these, 10 credit the Regina Research Station for herbicide residue studies, and an additional 24, dealing with herbicide efficacy and tolerance, credit 8 other Agriculture Canada Research stations.

Minor use program (linuron in asparagus)

In a 2-year study, residues of the herbicide linuron were monitored in asparagus spears that had been treated with preemergence applications of 1.1 and 2.2 kg/ha at two sites in British Columbia (Agassiz and Summerland). Residue determinations were made using a high performance liquid chromatography (HPLC) method that gave recoveries in the order of 90% from asparagus tissue fortified at the 10 µg/kg level. Asparagus spears that emerged at the time of application were collected as postemergence-treated samples, whereas those that emerged after application were collected as preemergence-treated samples. Maximum linuron residues detected in the preemergence samples were in the order of 10 µg/kg, whereas maximum residues in the postemergence samples were greater than 400 µg/kg.

Clopyralid breakdown in soils

Extraction and gas chromatographic analytical procedures were developed for clopyralid in soils. Recoveries of the herbicide, from three soil types fortified at the 0.1 ppm level, were over 90%. The laboratory breakdown of clopyralid in clay, clay loam, and sandy loam soils at 85% field capacity moistures and at 10°, 20°, and 30°C was investigated. The soil breakdown was dependent on temperature and soil type. The results indicate that carry-over of this herbicide can be expected in Saskatchewan field soils under conditions of deficit moisture.

Glufosinate breakdown in soils

Procedures for the extraction and gas chromatographic analysis of the herbicide glufosinate in several soil types, at the 0.1 ppm level, were developed. Gas chromatographic and radioactive techniques were used to study the laboratory breakdown of [^{14}C]glufosinate in a clay, clay loam, and sandy loam at 20°C and 85% of field capacity. Breakdown was rapid, with 50% of the applied herbicide biologically degraded in 7–10 days. Only one degradation product was isolated and identified. The dissipation of glufosinate at 1 kg/ha was studied at three Saskatchewan field sites. In all soils, breakdown of the herbicide was rapid and complete by the end of September. In all soils, the loss of the degradation product was slower than that of glufosinate. There was no leaching of either the herbicide or degradation product, at any site, to soil depths below 10 cm. These results indicate that there should be no recropping problems with glufosinate.

Long-term effect of 2,4-D and MCPA application

The rate of breakdown of 2,4-D in soils from the long-term plots at Indian Head that had received 40 prior annual applications of the herbicide was investigated under controlled laboratory conditions. Similar studies were also conducted with MCPA in soils from plots receiving 34 annual treatments with the chemical. The breakdown of both herbicides was significantly faster in soils that had received continuous applications than in soil from control plots with no prior treatments. This finding indicates extensive soil microbial adaptation in response to long-term use of these herbicides, resulting in a faster field dissipation.

AGRONOMY

Soil conservation production systems

Since 1986 the Indian Head Experimental Farm has been conducting extensive research on crop production systems that address soil conservation. These systems are being investigated for three different soil types (Meota fine sandy loam, Yorkton light loam, and Oxbow loam) in east-central Saskatchewan, and on a heavy clay soil at Indian Head. Special attention is being given to comparing zero tillage,

minimum tillage (only one preseeding tillage operation), and conventional tillage (fall and spring tillage operations). The three tillage systems are superimposed on various crop rotations that include cereal and oilseed crops as well as pulse crops at the Indian Head site.

The agronomic and economic results from east-central Saskatchewan favor a crop production system that incorporates minimum tillage and continuous cropping. After 3 years, the weed spectrum and densities were similar for all three tillage systems at all sites in east-central Saskatchewan.

The results from Indian Head were more definite. After 3 years, the net returns were superior for the zero and minimum tillage systems, compared with the conventional tillage systems. In 1988, yields of flax, spring wheat, and field peas on zero and minimum tillage exceeded those on conventional tillage by at least 30%. An effort is being made to quantify, in as much detail as possible, the changes with respect to leaf and root diseases, weed populations, and plant–soil water relations caused by changes in tillage systems.

At all locations, plant establishment and plant populations were not affected by tillage systems. The yields have been similar for all three tillage systems regardless of crops used or locations, except at Indian Head, where the 1988 yields with conservation tillage were superior. The results do not support the popular view that changing tillage systems results in lower yields in the short term. On the contrary, benefits were obtained during the first year for flax grown on zero and minimum tillage at Indian Head.

Green foxtail control in annual canarygrass

Production of annual canarygrass (*Phalaris canariensis* L.) has declined in some areas in the past few years, primarily because of infestations of green foxtail (*Setaria viridis* (L.) Beauv.). At present, a propanil plus MCPA tank mix is the only herbicide treatment registered for green foxtail control in annual canarygrass. The treatment must be applied before the three-leaf stage, and producers believe that crop tolerance problems exist with the use of propanil on canarygrass.

Fenoxaprop-ethyl, fenoxaprop-ethyl combined with 2,4-D, MCPA, bromoxynil, bromoxynil plus MCPA and dicamba, and propanil plus MCPA were evaluated for their efficacy in controlling green foxtail and for tolerance on canarygrass.

Differential susceptibility of the two grass species to fenoxaprop-ethyl and modifications of this phenomenon by the addition of growth regulating herbicides to the treatment were detected in greenhouse trials. In the field, green foxtail control with fenoxaprop-ethyl and fenoxaprop-ethyl mixtures was generally better than the recommended treatment, propanil plus MCPA. Athough significant reductions in green foxtail numbers occurred, yield advantages were not realized. Visual crop tolerance was commercially acceptable, except with the high rate of fenoxaprop-ethyl alone (200 g/ha) in 2 years out of 3, and fenoxaprop-ethyl plus bromoxynil in 1 year.

Fenoxaprop-ethyl and fenoxaprop-ethyl mixtures were generally more effective than propanil plus MCPA in reducing green foxtail numbers and seed production, without reducing canarygrass yield.

SEED INCREASE AND DISTRIBUTION

In 1988 Agriculture Canada released to the SeCan Association seed of the new cultivars Chapais barley (2520 kg), Frank triticale (211 kg), Robert oats (1473 kg), Kirk crested wheatgrass (46 kg), and Laura wheat (12 312 kg). In addition, 79 900 kg of Laura wheat were brought to the Indian Head Experimental Farm for reshipping.

There were 1050 kg of HY 355 wheat and 2500 kg of HY 368 distributed to the Canadian Wheat Board Market Development Office for increase for test marketing.

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INTRODUCTION

This report covers the results of work completed in 1988 at the Saskatoon Research Station and at the Scott Experimental Farm, 160 km west of Saskatoon. Four research programs are conducted. These programs include multidisciplinary research on breeding and agronomy as well as on control of diseases, weeds, and insects on oilseed, forage, and cereal crops. We have the major responsibility in the Research Branch for research on canola–rapeseed and mustard. Saskatoon, along with the Lethbridge and Kamloops research stations, is an integral part of the branch's research program on development of bloat-safe alfalfa. We also have a major responsibility for the development of forage grasses for the northern prairies. The cereal program is concerned mainly with reducing losses from common root rot in wheat and barley and with the breeding of utility wheats. The integrated pest management program deals with the development of control systems for problem insects (i.e., grasshoppers, wireworms, wheat midge, and black flies) that are not specifically restricted to any one commodity. A major objective in the program is to minimize our dependence on insecticides for the control of these pests.

Reports and reprints of publications can be obtained from the Saskatoon Research Station, Research Branch, Agriculture Canada, 107 Science Crescent, Saskatoon, Sask., S7N 0X2; Tel. (306) 975-7014.

J.R. Hay
Director

OILSEEDS

Breeding

Development of low-glucosinolate mustard. Low-glucosinolate mustard (*Brassica juncea* Coss.) was developed from an interspecific cross between an Indian-type glucosinolate-containing *B. juncea* selection and low-glucosinolate *B. campestris* L. A BC_1F_3 plant, number 1058, was found to contain less than 1 µmol total aliphatic glucosinolates per gram of meal. The glucosinolate content of individual plants of the BC_1F_4 generation from plant 1058 ranged from 0.8 to 2.9 µmol per gram of meal. Field-grown progeny of plant 1058, at three locations in 1987 and at one location in 1988, contained less than 10 µmol of glucosinolates per gram of meal. The low-glucosinolate characteristic of selection 1058 is considered to be genetically stable. Progeny of plant 1058 had the gross morphology, chromosome number, and seed coat reticulation characteristic of *B. juncea*.

This achievement will allow the breeding of canola-quality *B. juncea* mustard. Currently grown cultivars of condiment mustard (*B. juncea*) cultivars such as Domo or Cutlass yield, on average, 10–15% more seed than the canola cultivar Westar (*B. napus* L.). Mustard is better adapted to drier and hotter parts of the prairies and is highly resistant to blackleg. It is expected that a canola-quality mustard will greatly increase the potential for canola production in western Canada, but will not replace existing canola species in the north.

Diseases

Races of white rust. Saskatchewan collections of white rust, *Albugo candida* (Pers. ex Lév.) Ktze., from *Raphanus sativus* L., *Brassica juncea* (L.) Czern., *Capsella bursa-pastoris* (L.) Medic., and *B. campestris* L. represented four races. Races were differentiated on *R. sativus*, *B. juncea* L.'Southern Giant Curled', *Capsella bursa-pastoris*, and certain cultivars of *B. campestris* ssp. *pekinensis* (Lour.) Olsson. Some accessions of Indian yellow and brown sarson, *B. campestris* ssp. *sarson* Prain, were susceptible to both the *B. juncea* and the *B. campestris* races. The collection from radish was judged not to be a serious threat to the production of canola–rapeseed or condiment mustard in western Canada. The collection from *Capsella* did not infect any *Brassica* cultivars. The *B. juncea* race infected less than 10% of the plants of *B. campestris* L. 'Torch' and 'Tobin', but infected up to 35% of the plants in the cultivar Candle and 59% of the plants in a *B. campestris* breeding line from Finland. *B. napus* L. (rape and rutabaga) was highly resistant to all the races. A few yellow sarson accessions from Nepal were resistant to both

the *B. campestris* and *B. juncea* races and are important from the perspective of resistance breeding. Sources of resistance to the *B. juncea* race were found in both brown and Oriental mustards from the USSR. Resistance to the *B. campestris* race was found in accessions of *B. campestris* ssp. *eu-campestris* (L.) Olsson from North America, Central America, and South America.

Inheritance of resistance to white rust in mustard. The inheritance of resistance to white rust *Albugo candida* (Pers. ex Lév. Ktze.) in mustard, *B. juncea* (L.) Coss., was studied in crosses involving one resistant and two susceptible cultivars. The reaction of the F_1 was like that of the resistant parent, indicating that resistance is dominant and controlled by nuclear genes. Backcrosses of F_1 plants to the resistant parent showed the same reaction as that of the resistant parent. Backcrosses of the F_1 to the susceptible parents segregated in a 1:1 ratio of resistant to susceptible. The F_2 segregation of resistant and susceptible plants gave a good fit to a 3:1 ratio. The study revealed that resistance is monogenic and could be easily transferred to adapted susceptible genotypes through backcrossing.

Heritability of resistance to sclerotinia. Twenty-five cultivars and strains representing five *Brassica* species were tested under controlled conditions for their reaction to infection by *Sclerotinia sclerotiorum* (Lib.) de Bary, the causal agent of sclerotinia stem rot. Using the rate of stem lesion expansion as an indicator of the resistance of stem tissue to the pathogen, significant differences were present between species as well as among cultivars and strains within species. Although heritability of stem lesion expansion was low, plants of *Brassica campestris* L. and *B. juncea* (L.) Czern. with increased resistance to sclerotinia stem rot could be selected.

Toxin produced by blackleg fungus. A new fungal toxin produced by the causal agent of blackleg, *Leptosphaeria maculans* (Desm.) Ces. & de Not., was isolated and its phytotoxicity was examined. Sirodesmin H is the first example of a monosulfur bridged dioxopiperazine and is about 10 times less phytotoxic than Sirodesmin PL, the major toxin produced by *L. maculans*.

Differentiation of blackleg strains. A method was developed for the rapid differentiation of the virulent strain of *Leptosphaeria maculans* (Desm.) Ces. & de Not. (*Phoma lingam* (Tode ex Schw.) Desm.) from common weakly virulent isolates of *L. maculans* and other *Phoma* species. The test is based on differences in germ tube length after incubation for 40–44 h on agar containing antibiotics. Often, it was not necessary to obtain the fungi in pure culture on agar before testing. The main value of the test could be its use in conjunction with the 2,4-D blotter test for identification of the virulent strain of *L. maculans* from *Brassica* seed.

Detection of metalaxyl in rape plants. A bioassay procedure using *Pythium ultimum* Trow. and agar strips was sensitive and quantitatively accurate in detecting metalaxyl in rape tissue extracts. A linear response was obtained when assay values for both pure metalaxyl and a 50% WP formulation were plotted against the logarithm of chemical rates. Extraction procedures for recovering fungicide from plant tissues varied from 90% at 500 µg/500 mg tissue to 20% for 7.8 µg. Metalaxyl was detected in the foliage of the seedlings grown from seed treated with metalaxyl. Seedlings contained metalaxyl at a rate of 0.30, 0.19, and 0.23 µg per plant at 5, 7, and 9 days of age, respectively. Bioassay and gas chromatographic analysis of plant tissue extract confirmed the presence of metalaxyl in tissues remote from the site of treatment. Both bioassay and chemical analysis of plants grown in metalaxyl-drenched soil showed that the fungicide was readily taken up by plants from the soil solution, that the greatest accumulation was in the lower leaves, and that metalaxyl was found in decreasing amounts in leaves furthest from the roots and in only small concentrations in the stem and inflorescence.

Insects

Survey of thrips in canola fields. Adults of nine species of thrips from Saskatchewan canola fields were identified. The species were *Aeolothrips fasciatus* (L.); *Anaphothrips obscurus* (Müller); *Frankliniella occidentalis* (Perg.) (western flower thrips); *Frankliniella tritici* (Fitch) (eastern flower thrips); *Limothrips denticornis* Haliday; *Odontothrips loti* (Haliday); *Thrips* nr. *fuscipennis* Haliday; *Thrips tabaci* Lindeman (onion thrips); and *Thrips vulgatissimus* Haliday. The eastern flower thrips was the most abundant, and of all of the species it seems to have the greatest potential for becoming a significant pest of canola in Saskatchewan. It was followed in abundance by the onion thrips and *T. vulgatissimus*.

CEREALS

Diseases

Inheritance of resistance to common root rot. Heritability, effective gene number, and genetic effects for disease reaction to *Cochliobolus sativus* (Ito & Kurib.) Drechsl. ex Dastur in two crosses of spring wheat were estimated by partitioning genetic and environmental variance components. In the F_1 generation of the cross H-105 × H-186, the mean disease rating was intermediate between the resistant parent H-105 and the mid-parent value, pointing to incomplete dominance for resistance. Heritabilities estimated from family means of the F_3, F_4, and F_5 generations were greater than 70%, indicating that selection for resistant families may begin in early generations. Additive genetic effects were greater than dominance genetic effects, and there were small but significant epistatic (additive × additive) interactions. In the F_1 generation of the cross H-159 × H-186 resistance was completely dominant. Heritabilities among family means ranged from 32% in the F_3 to 78% in the F_5 generation, indicating that selection for resistance should be practiced in advanced generations. Additive and dominance genetic effects were equal, and no significant epistatic interactions were observed. Resistance to common root rot appeared to be controlled by at least three genes in both crosses.

Genetic markers in common root rot. In *Cochliobolus sativus* (Ito & Kurib.) Drechsl. ex Dastur, populations of randomly isolated ascospores from various crosses were analyzed to determine the inheritance of some attributes. White, tan, and brown (wild type) conidial colors were controlled by various alleles of a gene that segregated independently of one controlling mating type. A requirement for thiamine appeared allelic to prototrophy, and it was inherited independently of conidial color. The thiamine requirement and one for arginine were linked. A unisexual male reaction expressed by white-spored strain J26 appeared because of blocks in its female function. In crosses of this strain with dark-spored ones, white pseudothecia or white prototheca did not develop. The impairment in female function apparently was controlled by two genes that segregated independently of those for mating type and conidial color. These additional genetic markers may be useful in determining the genetics of virulence in *C. sativus*.

Inoculum density and common root rot. Common root rot was assessed in wheat cultivars grown at field sites in Queensland, Australia, having low, intermediate, and high inoculum densities of *Cochliobolus sativus* (Ito & Kurib.) Drechsl. ex Dastur. The densities at seeding time in the upper 10 cm of the profile were 3, 77, and 132 viable propagules per gram of soil, respectively. Both incidence and intensity of disease at tillering, flowering, and firm dough stages of plant development appeared closely related to inoculum density. Additional inoculum applied with seed increased disease markedly at the site of low inoculum density, slightly at the intermediate site, and had no effect at the site of high inoculum density, indicating a threshold level for maximum disease in the test. Reduction in dry weight of plants at the low and high sites paralleled the disease levels at the tillering and flowering stages. The relative reactions of the cultivars were expressed consistently: Songlen and Timgalen invariably were more diseased than Kite and QT2338/9. The results suggest that cultivars may be evaluated for resistance in the field from tillering onward if disease levels are adequate. *C. sativus* was the dominant fungus isolated from the subcrown internodes of plants from noninoculated subplots. Its frequency of isolation was much less from the site of low inoculum density than from the sites of intermediate and high inoculum density, and lower from Kite and QT2338/9 than from Songlen and Timgalen. *Fusarium chlamydosporum* Wollenw. & Reinking was isolated from subcrown internodes with increasing frequency as the season progressed. However, it was considered to be a secondary invader of the plant material.

FORAGES

Sainfoin

Tannin formation in tissue culture. Cotyledons from aseptically grown seedlings of sainfoin, *Onobrychis viciifolia* Scop., were used as explant material to grow callus tissue for periods of 21 and 31 days. The formation of cells containing condensed tannins was induced by adding the cytokinin 6-benzaminopurine (BAP) to a culture medium containing

2,4-D. After 21 days, the fresh weight of calli treated with BAP was much greater than the control and appeared highest at the 0.6 mg/L level. Fresh weight was reduced at high BAP levels (2–8 mg/L) but still remained well above the control. The formation of tannin-filled cells was genotype-specific but occurred in all treatments with BAP. After 21 days in culture, fresh weight and tannin formation increased with the BAP level at the lower BAP concentrations. After 31 days, the growth rate slowed in the control and the lowest BAP concentration but continued at a high rate in the remaining treatments. In general, the number of tannin-filled cells appeared to decline after 21 days. Thus, in sainfoin callus culture, BAP induced the formation of condensed tannin, a secondary metabolite, and concomitantly produced a high growth rate.

Grasses

Response of bromegrass to fertilizer. A 5-year study was conducted on Dark Brown loam at Scott, Sask., and a 9-year study on a Gray Luvisolic loam at Loon Lake, Sask., to determine the effects of ammonium nitrate and urea in bromegrass production and quality, N use efficiency, and N recovery. The N fertilizers were applied in a single application at the start of the experiment. The effects of P and S, applied to ensure adequate levels, were also assessed. Each N source was applied at single rates of 0, 100, 200, 400, and 800 kg/ha and annual rates of 0, 50, 100, and 200 kg/ha.

At Scott, forage dry-matter yields were positively related to precipitation received in April–June and in April of the crop year plus the previous September. Over the first 4 years, annual application of N resulted in up to 37% more dry matter than did single applications. Dry-matter production was generally greater with ammonium nitrate than with urea, especially at medium N rates. Dry matter was increased by P only when N was applied. N concentration in forage was directly related to N rate in years of good precipitation; it was greater in dry than wet years and when N was applied annually, but was not affected by N source. Phosphorus fertilization increased P concentration in forage, but high dry-matter yields reduced P concentration. Toxic concentrations of NO_3-N in forage occurred in the first year only at N rates of 200 kg/ha or greater and were related to N rate. Except for the N rate of 800 kg/ha in the second year, no further indications of NO_3-N toxicity were found. Accumulated efficiency of N use decreased linearly with increasing N rate and was greater for ammonium nitrate than for urea, except at very high N rates. Over the first 4 years, accumulated N recovery was greater for the single application at low N rates but was greater for annual applications at high N rates. P fertilization increased N recovery.

At Loon Lake, forage dry-matter yields were positively related to precipitation received in May–July and April–May, but negatively related to June precipitation. Forage dry-matter production was greater over the first 8-year period for annual N applications than for single applications receiving an equivalent amount of N. Dry-matter yields were 19% greater after 4 years and 26% greater after 8 years when ammonium nitrate was used compared with urea. Recovery of fertilizer N in forage also favored ammonium nitrate. Application of low to moderate N rates depressed forage N and P concentrations when yield response was high, but concentrations were increased by the highest rates of N and by repeated annual applications. Toxic concentrations of NO_3-N occurred in forage in the first year when N was applied at or above 400 kg/ha as one application and in the second year when N was applied at 800 kg/ha. When N was applied annually at 200 kg/ha, NO_3 toxicity became a potential problem in later years as soil mineral N accumulated. P and S fertilizers increased dry-matter yields. Annual N applications resulted in more uniform annual yields and N uptake compared with single applications and provided greater total dry-matter production without loss of quality.

INTEGRATED PEST MANAGEMENT

Wheat midge

Survival of wheat midge eggs and larvae. The spatial and statistical distribution of eggs and larvae of the wheat midge, *Sitodiplosis mosellana* (Géhin), in wheat in northeastern Saskatchewan was investigated. The highest number of each stage occurred in the top third of the head and the lowest in the bottom third. Because of this the entire wheat head is considered an adequate sample unit for density estimates of the two life stages. Sample sizes required to estimate egg and larval populations with given levels of precision were

determined. A sequential sampling plan for larval populations was derived using two methods referred to in the literature. Both methods gave similar results; however, the number of samples required to reach a decision was higher using one method than the other.

Laboratory rearing of the wheat midge. The orange wheat blossom midge, *Sitodiplosis mosellana* (Géhin), was reared through one complete generation in the laboratory. For the adult stage, avoidance of handling, the maintenance of at least 60% RH, low night temperature, and the provision of wheat plants at the correct flowering stage for oviposition were important factors for survival. For larvae, adequate soil moisture was essential to induce them to leave their ecdysial sheaths, to penetrate the soil before diapause, and to promote diapause development. Adult emergence ranged from 10.6 to 51.6%. At least 112 days at 2°C was required for optimal emergence of adults.

Insecticides for wheat midge control. The efficacies of cypermethrin, deltamethrin, permethrin, endosulfan, methoxychlor, carbofuran, chlorpyrifos, dimethoate, and malathion were evaluated against the wheat midge, *Sitodiplosis mosellana* (Géhin). Methods were described for evaluating damage and protection in individually collected wheat heads and whole plants. Weighted values from whole plants provided the best indication of kernel protection and yield response.

Whole plants contained three main types of wheat heads (primary heads, first tillers, and second tillers), which differed in their frequency, number of kernels, number, and developmental time. Developmental time indicated that the chronology of midge attack, status of midge infestations during spraying, and spray coverage also differed in the head types.

Insecticides provided various levels of kernel protection within and among the various head types. The majority of primary heads emerged before spraying and harbored midge eggs at spraying. In these wheat heads, chlorpyrifos, endosulfan, and malathion provided significantly better kernel protection (60–75%) than did permethrin, deltamethrin, and cypermethrin (<7%). The results suggested that the more effective kernel protectants permeated the spikelet and controlled the eggs or newly hatched larvae, or both. Kernel protection in the primary heads was closely related to insecticide volatility. In first and second tillers that emerged after spraying, poor spray coverage of the wheat heads and short residual activity of all insecticides against the adult midge appeared to limit kernel protection.

Aerial applications for the control of wheat midge. Evaluation of individually collected wheat heads and whole plants indicated that several factors may influence the efficacy of aerial sprays against the wheat midge, *Sitodiplosis mosellana* (Géhin). These factors related to methods of assessing midge damage, condition of wheat heads during spraying, and methods of spray application. Influences related to location and distribution also were important.

Efficacy assessments were based on reductions in midge larvae, midge-damaged kernels, and percentage of kernel damage. Data on percentage of kernel damage were confounded by differences in number of kernels within wheat heads. In head and plant samples, sprays were more effective at reducing the number of midge larvae rather than reducing the incidence of midge-damaged kernels. Evaluation of individual heads overestimated the efficacy of sprays in whole plants with one primary head and two tiller heads. Sprays provided more effective midge control and kernel protection in the primary heads, which emerged before spraying, than tiller heads, which emerged mainly after spraying. Protection was usually better in apical regions than basal regions of each head type. In whole plants, efficacy declined as tillering increased.

Plant evaluations indicated that the high-volume (37.4 L of water per hectare) chlorpyrifos spray provided the best midge control and kernel protection (95% and 87%, respectively), followed by the low-volume (18.7 L of water per hectare) chlorpyrifos spray (87% and 76%, respectively) and low-volume dimethoate spray (66% and 53%, respectively). When improvements in both yield and grade were considered and calculations were based on 1987–1988 wheat prices, net returns from the three aerial sprays ranged from $62 to $113/ha. Long-term benefits of the sprays probably were less favorable. Reduction in wheat midge after spraying would negate the benefits of an egg-larval parasite, *Pirene penetrans* (Kirby), which was present in low numbers.

Grasshoppers

Fungal pathogens of grasshoppers. A survey of grasshopper populations in Saskatchewan and Alberta indicated that the fungal disease caused by *Entomophaga grylli* Fresenius, pathotype II, was present in melanopline grasshoppers in 1985 and 1986. In Saskatchewan the disease was more prevalent and widespread in 1986 than in 1985. It was found in 44% of 128 survey sites in 1986 compared with 11% of 190 sites in 1985. In Alberta a high incidence (more than three per 100 m^2) of infected grasshoppers was found at 6% of 1746 sites in 1986 as compared with less than 1% of 2055 sites in 1985. Levels of infection based on cadaver densities at sites with a high incidence of disease in Saskatchewan were similar in both years, ranging from 3 to 28% for the total population. *Melanoplus bivittatus* (Say) was the predominant host species for *E. grylli* pathotype II; *M. sanguinipes* (F.) was less affected. *E. grylli* pathotype I was isolated from *Camnula pellucida* (Scudder) from a few sites in both Saskatchewan and Alberta in 1986.

Protozoan parasite of grasshoppers. The life history and ultrastructure of the protozoan *Malameba locustae* (King & Taylor) were studied in the migratory grasshopper *Melanoplus sanguinipes* (F.) using feeding and injection studies. Insects that were fed cysts developed infection in the Malpighian tubes 5–6 days later; no trophozoites were observed in hemolymph samples taken 2–20 days after feeding. After excystment, a few trophozoites entered the midgut epithelium and many were located near the basement membrane of the epithelial cells, where they appeared to degenerate. Trophozoites were not seen to divide in the midgut epithelium and apparently did not damage this tissue. Trophozoites injected directly into the hemocoel could not be recovered even 4 h after injection, and the Malpighian tubules did not become infected. It was concluded that trophozoites did not penetrate the midgut to enter the hemocoel or move through the hemocoel to infect the Malpighian tubules, but instead probably entered the tubules directly from the gut. Trophozoite ultrastructure in midgut and Malpighian tubules, and cyst wall deposition, were described.

Isolation of grasshopper pathogens. Aspergillus parasiticus Speare and *Beauveria bassiana* (Bals.) Vuillemin were isolated from melanopline grasshoppers in Saskatchewan in 1986 and 1987. The pathogenicity of these isolates for *Melanoplus sanguinipes* (F.) nymphs was assessed by topical, oral, and injected applications of 1.0×10^3, 10^4, or 10^5 conidia per individual. The *A. parasiticus* isolate was pathogenic to *M. sanguinipes* by injection and topical application but not orally. The *B. bassiana* isolate was pathogenic when injected or topically applied, resulting in high mortality (82–100%) at all doses tested, between 3 and 5 days after inoculation. *Beauveria bassiana* was infectious, at the highest dose tested, when orally applied, with most mortality occurring 7–14 days after inoculation.

Resistance of cereal cultivars to grasshoppers. A laboratory test was developed to screen cereal crops for resistance to grasshoppers, *Melanoplus sanguinipes* (F.), using mean weight and survival of the first two instars. When 22 modern cultivars (11 wheats, four oats, three ryes, and four barleys) were tested, survival ranged from 95% on wheat (Sinton) to 85.7% on oats (Harmon). Percentage of survival was more variable than the mean weight of measurements. Mean weight of grasshoppers after 5 days of feeding was highest for wheat (Glenlea) and lowest for the four cultivars of oats. Mean weight of grasshoppers fed on HY320 was significantly lower than for all other wheat cultivars. There was no correlation between either growth rate or survival of grasshoppers and percentage of nitrogen in the cultivar foliage.

Differential feeding by grasshoppers. Sixty-four cultivars and strains of cereals were evaluated under field conditions for differential feeding by grasshoppers (Orthoptera: Acrididae) and for their resistance to foliar disease. Grasshoppers fed actively on all triticale and durum wheat lines, on 11 of 12 bread wheat lines, and on 11 of 24 barley lines. Both the incidence and severity of foliar disease were high in all cereals. There was no correlation between grasshopper damage and resistance to foliar disease ($r = -0.059$) in the barley, but a positive trend appeared in wheat lines (bread $r = +0.487$; durum $r = +0.295$). The data suggest that present trends in breeding disease-resistant cereal cultivars will not introduce increased susceptibility to grasshopper damage.

Research Station, Saskatoon, Sask.

Pesticide chemistry

Terbufos residues. Granular terbufos (Counter 15G) was applied in furrow at time of planting of wheat and barley. Total terbufos residues were determined as terbufoxon sulfone in foliage collected at several times. In wheat foliage, maximum residues of 7.4 and 10.6 parts per million (ppm) from application of 1.5 and 3.0 kg/ha occurred 10 days after seeding. Wheat foliage collected 53 days after seeding had residues of 0.32 and 0.58 ppm from the applications consisting of 1.5 and 3.0 kg/ha. Residues in barley were consistently less than in wheat, with 4.4 and 7.0 ppm detected in foliage collected 10 days after seeding and 0.21 and 0.34 ppm detected at 53 days after seeding. Residues of 0.01 ppm or less were detected in both of the grain samples at harvest. Straw samples had up to 0.75 ppm total residue of terbufos at harvest.

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Swift Current, Saskatchewan

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Departures

S.D. Hanson Resigned 23 September 1988	Programmer–Analyst
T.F. Townley-Smith, B.S.A., M.Sc., Ph.D. Transferred to Winnipeg Research Station March 1988	Cereal breeding

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[1] Seconded from Libraries Division, Corporate Management Branch.
[2] On transfer of work, Colorado State University, Fort Collins, Colo., September 1988 to August 1989.

INTRODUCTION

The research program at Swift Current encompasses breeding, physiology, and agronomy in wheat (hard red spring, durum, and Canada prairie spring) and rye; breeding, agronomy, ruminant nutrition, and pasture management in forage crops; engineering, hydrology, fertility, agrometeorology, economics, and soil chemistry in soil and water management; and turkey nutrition. Research programs are designed to solve production problems and to evaluate new opportunities that will enable Canadian farmers, especially those located in the semiarid Palliser Triangle, to maintain or improve their competitive position in domestic and foreign markets.

The research strength of the station was reduced in 1988. Dr. T.F. Townley-Smith, wheat breeder, transferred to the Winnipeg Research Station, and S. Hanson, programmer–analyst, resigned.

Examples of significant new developments in research include evaluation of energy efficiency of cropping systems in southwestern Saskatchewan, development of a method to estimate rate of release of nitrogen from soils, assessment of the effect of foliage color on the seed and forage yield of Altai wild ryegrass, and registration of Frank triticale, Tetracan Russian wild ryegrass, and two varieties of Dahurian wild ryegrass. Also, the potential productivity of a Brown loam soil was shown to improve by zero till management when properly fertilized. Turkey nutrition studies evaluated various pharmaceutical products as feed additives for their effects on production efficiency and product quality.

Three scientists received major awards in 1988. Dr. C.A. Campbell became a Fellow of the Agricultural Institute of Canada and a Fellow of the Canadian Society of Soil Science. Dr. T. Lawrence received the Outstanding Research Award from the Canadian Society of Agronomy and the Award of Merit from the American Forage and Grassland Council. Dr. R.M. De Pauw was presented the Distinguished Agrologist Award by the Saskatchewan Institute of Agrologists.

This brief report contains highlights of recent findings of our research programs. More detailed results can be obtained from our annual *Research Hi-Lites*, from published papers, or by direct contact with the Research Station, Research Branch, Agriculture Canada, Box 1030, Swift Current, Saskatchewan, S9H 3X2; Tel. (306) 773-4621.

B.H. Sonntag
Director

CEREAL PRODUCTION AND UTILIZATION

Wheat

HY368 wheat. HY368 is a red spring wheat suitable for the Canadian prairie spring class. This cultivar has a hard kernel with improvements in milling quality and baking performance compared with the cultivar HY320. Yields are similar to HY320 in all of the agroclimatic areas of the prairies. HY368 outyielded Oslo by 6% in Manitoba and southeastern Saskatchewan and by 23% in the Brown and Dark Brown soil zones of southern Saskatchewan and Alberta.

HY368 appears to mature slightly earlier than HY320 and about 3 days later than Oslo. It has semidwarf stature and straw strength similar to HY320. It is resistant to shattering and to prevalent races of leaf and stem rust and is moderately susceptible to common root rot. HY368 is susceptible to both loose smut and common bunt.

Drought physiology

Rate of water loss from wheat leaves. Rate of water loss (RWL) from excised leaves has been proposed as a screening technique to identify wheat genotypes adapted to dry growing conditions. The relationship of RWL and grain yield was studied in 100 durum wheat (*Triticum turgidum* L. var. *durum*) genotypes grown at two locations in Canada and three locations in Syria. Fifty of the genotypes were chosen on the basis of low RWL and 50 on the basis of high RWL. Growing-season precipitation ranged from 73 to 356 mm. Genotypes with low RWL yielded more than those with high RWL in four of the five driest environments in 9 site-years of study. Yield of the low RWL

genotypes ranged from 40 to 150% greater than that of the high RWL genotypes at the four sites. The high RWL group did not yield more than the low RWL group ($P < 0.05$) in any of the site-years. Glaucousness confounded interpretation of the results because the low RWL group tended to be more glaucous than the high RWL group. Separation of the genotypes into groups of high and low glaucousness showed that the high group yielded more than the low group in the three driest Canadian sites and in the wettest site in Syria. Low RWL and high glaucousness were associated with delayed leaf senescence in dry environments. Low RWL was concluded to contribute to high yield under dry growing conditions and does not exhibit a metabolic carbon cost under more favorable precipitation regimes.

Harvest physiology

Factors affecting rate of water imbibition by wheat kernels. Rate of water imbibition by wheat kernels may be related to preharvest sprouting damage and tempering times during milling. The effects of kernel color and exposure to weather damage on water imbibition rate of wheat (*Triticum aestivum* L.) kernels and the effects of field versus oven drying and hand versus mechanical threshing on water uptake rate of HY320 wheat and Welsh triticale (*X-Triticosecale* Wittmack) were investigated. Rates of imbibition were determined by sequential weighing over a 32-h period of 50-kernel samples imbibing water from agar media. In HY320 wheat the rate was faster for mechanically threshed (0.0117 g/g per hour) samples than for those that were hand-threshed (0.0115 g/g per hour). Threshing method did not affect imbibition rate of Welsh triticale kernels (average 0.0141 g/g per hour). Rate of germination was significantly greater for mechanically threshed than for hand-threshed Welsh, but there was no significant difference for HY320. Method of drying did not affect kernel water imbibition rate. Rate of imbibition was faster in nonweathered than in weathered wheat (0.0136 versus 0.0130 g/g per hour). In five wheat crosses involving white and red kernel color, rate of water imbibition was not associated with the allele for kernel color. Rate was negatively correlated with kernel weight and kernel hardness in the five crosses and positively correlated with protein content. Other undetermined factors accounted for the major part of the genotypic differences in rate of imbibition.

Poultry nutrition

Hull-less barley for turkeys. Small white turkeys were fed diets containing hull-less barley (with or without a beta-glucanase enzyme source) or wheat, each supplemented with graded levels of vitamin D_3 and available phosphorus, to 12 weeks of age. The diets consisting of hull-less barley plus enzyme significantly increased liveweight over the hull-less barley or wheat diets by 4 weeks, but there was no difference at 12 weeks of age. At 4 weeks, birds fed the diets consisting of hull-less barley plus enzyme were as efficient in feed conversion as those fed wheat-based diets, but by 12 weeks birds fed both hull-less barley-based diets were less efficient than those fed the wheat-based diets. A significant cereal × available phosphorus × vitamin D_3 interaction at 4 weeks showed the pronounced effect of the lower dietary available phosphorus and vitamin D_3 concentration on reducing body weight of birds fed hull-less, barley-based diets without the beta-glucanase enzyme source. Mortality, incidence of leg problems, and carcass quality were not affected by diet. Tibia ash was greater for birds fed diets containing hull-less barley plus enzyme, 0.7% available phosphorus, or 2500 IU vitamin D_3 per kilogram of feed compared with those fed wheat or hull-less barley without enzyme, 0.4% available phosphorus, or 900 IU vitamin D_3, respectively

Results show hull-less barley plus an enzyme source can replace wheat as a major cereal grain in diets for turkeys. Birds fed hull-less barley plus enzyme can tolerate lower levels of vitamin D_3 and available phosphorus supplementation than those fed hull-less barley diets without the enzyme.

Dietary protein and leg disorders in turkeys. Diets varying in protein (24, 29, 34, or 39%), calcium (0.8, 1.2, or 1.6%) and available phosphorus (0.4, 0.8, or 1.2%) concentration were fed to Large White poults to 3 weeks of age. Treatments were then pooled according to the protein concentration of the starting diet, and birds were fed either the regime recommended by the National Research Council (U.S.A.) or a high protein dietary regime through the growing and finishing period. By 2 weeks of age the incidence of leg disorders was 4, 8, 12, and 15% in birds fed the 24, 29, 34, and 39% protein diets, respectively. By 3 weeks of age, tibia ash was reduced as dietary protein increased. By 20 weeks, liveweight was not affected by diet, but birds fed the high protein

growing–finishing regime had a higher incidence of twisted and weak legs than those fed the recommended level of protein.

These results indicate that feeding higher than recommended levels of dietary protein may predispose turkeys to early leg problems and increase the incidence at market age.

ENGINEERING

Energy

Alternative fuel control parameters for a diesel engine. Investigations were conducted to determine appropriate diesel engine parameters for the development of a dual fuel control system for agricultural use. A feedback signal representing engine power was concluded to be an essential characteristic of a dual fuel control system. Also, it was shown that engine power could be estimated by correlations with engine fuel consumption or exhaust energy rejection.

Energy efficiency of cropping systems. Nonrenewable energy input, metabolizable energy output, and the energy efficiency of 10 spring wheat (*Triticum aestivum* L.) crop rotations were examined over an 18-year period. The results showed that the total energy input per unit of land was lowest for the traditional fallow–wheat rotation (3482 MJ/ha), intermediate for well-fertilized fallow–wheat–wheat (4470 MJ/ha), and highest for well-fertilized continuous wheat (7100 MJ/ha). Substituting flax or rye for wheat in the rotations reduced total energy input modestly, and the elimination of one application of nitrogen or phosphorus fertilizer reduced energy input by 16–37%.

FORAGE PRODUCTION AND UTILIZATION

Grass breeding

Evaluation of Dahurian wild ryegrass. Dahurian wild ryegrass (*Elymus dahuricus* Turcz. ex Griseb.) is a short-lived but productive forage crop for western Canada. Dahurian wild ryegrass was found to be a self-pollinated bunch grass, showing variability in maturity and at least three distinct head types: purple, green floppy, and green erect. It was also found to have good seedling vigor, high dry-matter production, high seed yields, adequate digestibility, and palatability. It will provide a short-rotation hay or pasture crop and may be useful for increasing production from young stands of longer lived, slower growing forages seeded in widely spaced rows.

Two cultivars of Dahurian wild ryegrass were approved for registration.

Pasture management

Effect of nitrogen on beef production and forage quality of Russian wild ryegrass. Average annual applications of N at 30 or 61 kg/ha were made to pastures of Russian wildrye (*Psathyrostachya juncea* (Fisch.) Nevskii) from 1977 to 1987 to raise the available N present in the soil to 55 or 110 kg/ha. Additional treatments consisted of a once-only application of N at 390 kg/ha in April 1977 and a control treatment of no fertilizer. Pastures were grazed with yearling steers from early May until 5 cm of grass remained or when steers did not gain weight in a 2-week period.

Total beef production averaged 133, 147, 131, and 105 kg/ha, respectively, and grazing days were 168, 183, 168, and 130 days/ha, respectively, for steers on the four treatments. Fertilizer N increased carrying capacity 30–40% each year, even in years of below average rainfall, and prevented the decline in production often observed in seeded grass as an unfertilized stand ages.

Forage N and digestible organic matter were marginally increased by fertilizer N. Forage N and organic matter digestibility generally decreased through the season. Average daily gains of the steers were not affected by the treatments and decreased gradually as steer weight increased and forage quality declined.

SOILS AND ENVIRONMENT

Economics

Economics of tillage and rotation systems for winter wheat production. This study examined grain yields and net returns from producing winter wheat under 2-year, 3-year, and continuous crop rotations each using zero tillage and two methods of conventional tillage. The study draws on 7 years of data collected at Lethbridge, Alta. The results showed that the economics of zero-tilled winter wheat production were generally quite favorable. Net returns were often similar or higher with zero

tillage than with conventional tillage, especially in years when growing-season rainfall was low or when grain prices were expected to be high. In years with above normal rainfall, zero tillage was generally less profitable than conventional tillage when the winter wheat was grown in rotations that included fallow; but this was not the case when the winter wheat was grown continuously and downy brome infestations were low. The relatively poor economic performance of the zero tillage fallow-type rotations in years with favorable growing season rainfall was a result of the high costs of herbicides for control of weeds on fallow areas. Zero tillage was shown to offer producers substantial savings in fuel, machine repairs, labor, and machine investment; however, the high cash outlay for herbicides often offset much of these resource savings, including the increased revenue from higher grain yields.

Nutrient cycling

Predicting net nitrogen mineralization over a growing season. A nitrogen mineralization model was developed by combining the potentially mineralizable nitrogen (N_o) with functions representing the effect of temperature and soil moisture on the mineralization rate constant (k). The model was used to estimate net nitrogen mineralized in an Orthic Brown soil at Swift Current, Sask., under summerfallow; cropped–dryland; and cropped–irrigated conditions. Model output showed good agreement to field measurements, especially for the first 45–60 days, but thereafter tended to underestimate the measured data, particularly under cropped–dryland conditions. The model is not dynamic because it does not allow for N_o to be replenished continuously by nitrogen derived from decomposition of fresh residues and rhizosphere microbial biomass. Net nitrogen mineralized from this source might explain at least part of the underestimate predicted by the model. Other sources of possible discrepancy could be imprecision in measuring the mineralization of nitrogen and in estimating the parameters in the model. One of the main shortcomings of the model was that it underestimated the amount of nitrogen mineralized whenever the soil became very dry and was then rewetted by rainfall. This probably occurred because the latter process resulted in large flushes in mineral nitrogen in situ, whereas in the laboratory estimate of N_o and k, this effect is not adequately simulated.

Rotations and cropping systems

Snow and N fertilizer management for wheat in southwestern Saskatchewan. In the Brown soils of Saskatchewan, limited soil moisture prevails; consequently, a spring wheat (*Triticum aestivum* L.)–summerfallow rotation is commonly used by farmers. During the 21-month fallow, about 45 mm of extra moisture is conserved, but bare soil encourages soil degradation. Soil scientists suggest that use of snow management may allow conservation of as much moisture as summerfallow allows. Using zero tillage may reduce evapotranspiration, and, coupled with proper fertilizer management, could further improve moisture use efficiency. A 6-year study in which tall strips of standing cereal stubble were used to enhance snow trap resulted in an average 11 mm of extra water stored in soil. This extra water resulted in higher yields, especially in dry years. Yields were increased by N fertilizer rates of up to 100 kg/ha in years of favorable moisture, but N treatments did not affect yields in dry years. On average, the relative yield responses to N systems were rated 100, 98, 94, and 91 for spring deep-banded, fall deep-banded, spring broadcast, and fall broadcast, respectively.

Soil quality

Effect of 6 years of zero tillage and fertilizer management on changes in soil quality In the Brown soil zone of Saskatchewan, moisture is usually limiting; consequently, the predominant cropping system is a year of summerfallow followed by a year of spring wheat. Tillage in the fallow period results in severe soil degradation because of erosion. Scientists have suggested that producers might be able to overcome their economic and environmental problems by using cereal trap strips constructed at harvest to trap snow and increase moisture conservation, especially if this action were coupled with zero tillage continuous cropping and proper fertilizer management. A 6-year experiment in which the latter factors were investigated was sampled and analyzed for various soil properties. These measurements were compared with similar measurements made on the adjacent area that had been in fallow–wheat for 70–80 years. Results showed that the zero-till continuous wheat system has increased total organic matter, microbial biomass N, amino compounds, potential C and N mineralization rates, and

phosphatase activity in the top 7.5 cm of soil, but in most cases there was little change in the 7.5–15-cm depth. Bulk density was not affected by tillage or cropping, but soil aggregation was increased by a single year of cropping (compared with tilled fallow).

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[1] On secondment to Ottawa beginning February 1987.
[2] On transfer of work to Davis, Calif., December 1988 to December 1989.

INTRODUCTION

The Beaverlodge Research Station and the Fort Vermilion Experimental Farm make up the Northern Research Group, which has responsibility for research and technology transfer on agriculture in the northern half of Alberta and British Columbia (the Peace River Region), in addition to undertaking limited work in the Yukon and Northwest Territories. The land resource encompasses over 2.2 million ha of cultivated land, and the region has an agriculture land resource for development for an additional 7 ha. The research is targeted to adapting crops and cropping management to the environment and to soils of a northern climate lying largely north of latitude 53°N. About 20% of the soils are acidic (below pH 6.0). Growing periods are 70–134 days (base –2.2°C). In part, the short growing season is compensated for by extremely long days during May, June, July, and August, with 2121 yearly hours of bright sunshine. The predominant crops are barley, canola, wheat, forage grasses, and legumes for seed and honey.

The staff of 50 consists of 14 researchers who work under 10 Research Branch projects. We conduct breeding in barley, canola, wheat, and honey bees. Forage research is conducted on herbage production and in seed production of legumes and grasses, the former using leafcutting and honey bees for pollination. We conduct research in a wide variety of areas including bees and their management and diseases, soil physics, chemistry, nitrogen fixation, weeds, plant pathology, and climate.

In addition to our federal resources we have partners such as Farming for the Future, Alberta Research Council, and Western Grains Research Foundation, which contribute funds for research. Other clients, ranging from individual producers to commodity groups and agribusiness, contribute to our research in various ways. The newly formed Beaverlodge Research Station Advisory Committee is an example of the contribution that our partners in the provinces, universities, and farming enterprises make to improve our research. Our work is targeted to developing technology for the future. Long-term research is our mandate.

During 1988 the border closure to importation of honey bees from the United States because of the *Varroa* mite created problems for our honey producers, yet colony numbers and honey production at year end were near normal. Crop production was generally good to excellent, and a dry fall contributed to a good harvest of a high-quality product.

During 1988 Dr. Liu continued his transfer of work at the University of California, at Davis, to work on honey bee pathology including tracheal and *Varroa* mites. Students at Fairview College studying forage technology and apiculture spent several months of on-the-job training as future technicians with the station. Numerous scientific visitors from Canada, the United States, Thailand, and Japan were hosted by the scientists.

The brief reports that follow give results of research in 1988. Detailed information can be obtained from the publications listed in the report or by correspondence with individual research scientists or the station director. The addresses are Research Station, Research Branch, Agriculture Canada, Box 29, Beaverlodge, Alta. T0H 0C0, Tel. (403) 354-2212; and Experimental Farm, Research Branch, Agriculture Canada, Fort Vermilion, Alta. T0H 1N0, Tel. (403) 927-3253.

J.D. McElgunn
Director

APICULTURE

Breeding

Closed-population comparison of selected and control strains. The offspring of 10 queen honey bees were divided and kept in northern and southern Alberta; in each location, selected and control groups were established. A new generation of queens was reared each year, representing all 10 queen families in each of the four groups. The primary selection criterion was short-term gain for the colony at the beginning of nectar flow. The new queens were mated in four geographically isolated locations with drones from their 10 colonies. Sixteen colony traits were recorded for the test colonies.

Twelve traits differed between control and selected groups of the combined north and south apiaries. These traits included fall

colony weight, winter food consumption, number of *Nosema* spores per bee in the fall, colony population in May, capped worker and drone-brood area, colony population in June, brood viability, propolizing, pollen collection, disease resistance, and short-term gain. When data for the northern location were analyzed separately, a significant response to selection was noted for an additional colony trait, total honey yield, for which there was a 25.6% increase in productivity over the control colonies. Fourteen traits differed between the northern and southern groups. Differences between selected and control groups are attributed to selection, and between the northern and southern groups to their respective environments.

Management

Colony gains in Alberta. In Alberta, honey bee colony weights were recorded at Beaverlodge, 1977–1985; Falher, 1979–1983; Brooks, 1979–1980; Scandia, 1982–1983; and Spruce Grove, 1982–1983. Colonies were provided with a constant supply of 10–30 combs for honey storage during the summer nectar flow. The peak period for colony gains was the latter part of July and the beginning of August. Great fluctuations in gains occurred between and within seasons. As much as 12% of the net production for the entire season occurred in a single day, 28% in 3 days, 53% in 7 days, 86% in 14 days, and more than 100% in 21 days. During the nectar flow, the continuous provision of ample empty combs was concluded to be essential for maximum production, probably not only in Alberta but also in other areas of the world where nectar flows are intense and of short duration.

Evaluation of nuclei. Nuclei may become the mainstay of modern beekeeping for maintaining or increasing colony numbers and for overwintering queens. Six-frame nuclei were prepared in late July and wintered indoors. There was 15% mortality during the winter and another 3% that were eliminated in the spring as queenless or too weak for production of colonies. When the nuclei were moved outdoors, at least three frames and adhering bees were placed in a standard-sized brood chamber that had been prepared with honey and pollen frames. Twenty nuclei were evaluated for spring buildup and production. Average sealed brood was 3132 cm^2 and 4653 cm^2 on 5 June and 7 July, respectively. Mean honey production was 65.9 ± 8.0 kg. Two colonies became queenless during the season.

Pathology

Nosema infection of overwintering colonies. Winter survival of 194 honey bee (*Apis mellifera*) colonies was not affected adversely by *Nosema* disease. The number of *Nosema* spores per bee after medication in the fall and in the spring decreased logarithmically with an increase in the amount of fumagillin fed in the range of 200–800 mg ($r = -0.381$ and -0.323 for fall and spring, respectively; $P < 0.01$). The average number of spores (in millions per bee) for the surviving colonies in the spring was 10.15 ± 1.47, 4.93 ± 0.81, 2.76 ± 0.59, and 3.20 ± 1.59; and for the dead colonies, 16.02 ± 2.65, 6.48 ± 2.65, 7.32 ± 7.32, and 0, with fall feedings of 200, 400, 600, and 800 mg of fumagillin per colony, respectively.

Nosema control with thimerosal in vitro. A drastic ultrastructural change occurred in the sporont and sporoblast of *Nosema apis*, within the midgut of honey bees that were treated with thimerosal for 24 h. In both the sporont and the sporoblast, a disintegration of nuclei was observed. The cytoplasm was electron-lucent and ribosomes appeared to be reduced in number. These changes indicated that the death of the parasite took place long before the experiment was terminated. The drug is perhaps directly toxic to the *Nosema* parasites.

Effects of itraconazole on chalkbrood. The young sporocysts had a wrinkled sporocyst wall, numerous papillae on the wall surface, and the wall was granular and porous. In the itraconazole-treated culture, the walls of the young sporocysts were also wrinkled, but the characteristic papillae were replaced by larger lumps that were densely packed and that coated the entire surface of the sporocyst wall. The mature sporocysts' walls were smooth and possessed numerous papillae. In the itraconazole-treated culture, the walls of mature sporocysts were also smooth but possessed densely packed larger lumps instead of papillae. At higher magnification, each of the lumps was found to consist of numerous globules. No pores were observed because they were in the normal sporocyst wall.

Morphology of tarsal sensilla in Varroa jacobsoni. The group of hair at the distal end and dorsal surface of the tarsus consisted of sensillae of varying size and shape. In the centre of this hair group was a pit containing a minute dome-like protrusion, centrally located at the bottom. On the rim of this pit were

small, fine, and different-shaped pegs measuring 3–4 μm in height. The pit was surrounded by six sensillae, two of which were slender, curved, round-tipped, and porous; three of the remaining four were stout, and one had a pointed tip. All pegs and six sensillae were stained with crystal violet, and pores were visible on the walls of the two slender and curved sensillae. Surrounding these small sensillae were 12–16 large hairs measuring 12–79 μm in height. Two to three of the large hairs were slender, curved, and round-tipped. They were also stained with crystal violet. Seven to eight stout, straight hairs measured 16–32 μm in height and were stained with crystal violet only at the tip. Three to four of the longest hairs measured 68–79 μm in height and were not stained with crystal violet.

Queens

Evaluation of instrumentally inseminated queens. Instrumentally inseminated (II) queens were evaluated for their performance when substituted for naturally mated (NM) queens in 1-kg packages shipped to Beaverlodge, Alta. II queens were inseminated once with 8 mm^3 of semen. The NM queens were significantly heavier ($P < 0.05$) than the II queens (190 mg versus 174 mg) on 30 April but were not different on 23 July. Sealed brood area of NM queen colonies was 8% greater than that of II-queen colonies on 20 May but not significantly different on 16 June and 18 July. Honey production was not significantly different; II queen colonies averaged 81 kg and NM queen colonies 70 kg.

Spermatozoa of queens from 0 to 3 years old. Queen honey bees (*Apis mellifera*) were reared under optimal conditions between 1982 and 1985. Mean weight of queens at emergence was 213 ± 2.02 mg. At initiation of oviposition (designated 0 years) and after 1, 2, or 3 years in honey-producing colonies, mean numbers of spermatozoa in the spermathecae were 9.77 ± 0.79, 7.63 ± 0.85, 5.57 ± 0.64, and 2.08 ± 0.62 million, respectively; numbers declined logarithmically with age of the queen. Annual requeening of colonies may be unnecessary, if efforts are made to produce queens of the highest quality.

Queen weight and initiation of oviposition. The onset of oviposition of 1396 queens reared in 2 years in the Peace River region of Alberta ranged from 4 to 22 days after emergence, with a mean of 10.6 ± 0.1 days. There was evidence to suggest that some queens may start to lay eggs within 24 h after mating. No consistent correlation was found between queen weight at emergence and the onset of oviposition. Mean weight of queens was 211.2 ± 0.7 mg (range 160–266 mg) in 1981 and 222.6 ± 0.06 mg (range 173–273 mg) in 1982. There was a close association between maximum daily temperature and time of oviposition. A large number of queens mated at temperatures below 25°C.

Short-term storage and queen weight. In each of 2 years, imported queens from California were maintained in one of three storage methods: a four-frame queenless nucleus hive (NH); a strong two-chamber queenless queen bank (QB); or a temperature controlled incubator (I). In the first 17–19 days NH queens were laying and gained an average of 59 mg in 1984 and 92 mg in 1985. The QB queens lost 1 mg in 1984 and gained 10 mg in 1985, whereas the I queens lost 27 mg in 1984 and 11 mg in 1985. After they were switched to different treatments (i.e., NH to QB, QB to NH, and I to NH), queens in the NH–QB treatment lost 55 and 58 mg, queens in the QB–NH treatment gained 30 and 54 mg, and queens in the I–NH treatment gained 53 and 66 mg in 1984 and 1985, respectively. It took 10–14 days for QB and I queens to gain substantial weight after placement in NH. It is therefore important that any storage technique maintain queens in a laying condition to minimize delays in colony development.

CEREALS

Barley

The most advanced line in the Beaverlodge barley breeding program, BT663, received support for registration. It performed well in the 12 Peace River sites of the Alberta Regional Recommendation Trials in 1988. It is an early-maturing six-row feed barley, 1–2 days later than the early-maturing cultivar Jackson. It has excellent resistance to barley leaf scald. This line will be the earliest maturing Canadian barley carrying effective resistance to locally common biotypes of barley leaf scald. One-half tonne of breeder seed is available at the Indian Head Experimental Farm for the 1989 increase.

FORAGES

Shelter materials for leafcutting bees. Three materials (Loretex III, Monarflex Ultra, and Dura Film polyethylene), each with different textures (clear to coated), thickness (0.152 to 0.250 mm), and light transmittance (91–78%) were compared as covering materials for leafcutting bee shelters under growing conditions in forage-seed-producing areas in northwestern Canada. Tests at two locations at latitude 55°12' N and 58°23' N, over 5 consecutive years, indicated that all three materials were similar in performance. No differences were observed in the sex ratio of the leafcutting bees or in their production of viable cells.

Pollination of red clover. The use of the leafcutting bee, *Megachile rotundata* (Fabricius), as a pollinator of diploid red clover, *Trifolium pratense* L., was investigated in the Peace River region of northern Alberta over a 5-year period, 1983–1987 inclusive. Average seed yield with the use of this pollinator was 410 kg/ha as compared with 291 kg/ha for the control where the leafcutting bee was not used. Furthermore, in 4 of the 5 years of study, provision of leafcutting bees was associated with higher seed production. Reproduction of leafcutting bees pollinating red clover was comparable to that obtained on alfalfa. For each crop, about 96% of the cells produced were viable. Also, about 32% of these cells were females, i.e., a 2:1 ratio of males to females. It should be noted, however, that the ratio of cell increase was generally lower in bees pollinating red clover than in those pollinating alfalfa, but that the lowest increase obtained was 1.5, i.e., there was no bee loss, only a minimum gain of 50%. The results of the present study indicate that management of the leafcutting bee as a pollinator of red clover merits further investigation.

Herbage production from grass–legume stands. Herbage from stands that consist of alternating, solid-seeded strips of pure grass and pure legume (40, 60, or 80 cm in width), grown under various N fertilizer treatments, was compared with that from a conventional mixture for yield, quality, and botanical composition. The component species were smooth bromegrass (*Bromus inermis* Leyss.) and alfalfa (*Medicago sativa* L.). The N fertilizer treatments were as follows: N_0, no N applied; N_{gl}, N applied uniformly at a rate of 150 kg/ha to the grass and legume components; N_g, N applied at an average rate of 150 kg/ha but distributed only over plot areas seeded originally to the grass component. Dry-matter (DM) yield of grass declined progressively as strip width increased with N_0 and N_{gl} but remained constant for the three strip-culture stands with N_g. Digestibility of DM was 69.7, 69.9, and 70.8% for the 40, 60, and 80 cm strip-culture stands, respectively, compared with 69.0% for the conventional mixture. Legume content (DM basis) ranged from 73 to 80%, 50 to 53%, and 41 to 42% for the strip-culture stands with N_0, N_{gl}, and N_g, respectively, compared with 66 and 39% for the conventional mixture with N_0 and N_{gl}, respectively. Strip-culture stands have some potential for manipulating the grass-to-legume balance of herbage. They may provide a practical way to overcome the long-recognized difficulty of supplying optimal N fertilizer to grass plants in grass–legume associations, without relinquishing the N-fixing contribution of the legume plants.

Weed control. 2,4-D with active ingredient (a.i.) at 0.5 and 1.0 kg/ha was applied to bromegrass *Bromus inermis* Leyss. in September of the year of seeding or in the following spring at each of two crop stages: before stem elongation and at the shotblade stage. Seed yields 1 year after seeding were not significantly reduced by any of the herbicide treatments applied in September or by any of the 2,4-D treatments applied before stem elongation. However, seed yields averaged across the 3 years of the study were significantly reduced by applications of 2,4-D with a.i. at 1.0 kg/ha at the shotblade stage and by all spring applications of dicamba, except the rate of 0.15 kg/ha applied before stem elongation. Weight per 100 seeds and percentage of germination were not affected by any of the herbicide treatments.

ENVIRONMENT AND SOILS

Long-term effects of some cropping systems on a Gray Luvisol. In 1968 a study was initiated comparing four cropping systems on a Gray Luvisol soil. Cropping systems included continuous barley, continuous bromegrass (hay), continuous legume (red clover hay), and a 6-year rotation of barley–barley–barley and 3 years of bromegrass–red-clover mixture (hay). The results 20 years after its initiation: yields of barley following the mixed forage

were higher than continuous barley; and soil aggregates were more stable in the barley–forage rotation than continuous barley cropping. However, of all cropping systems, continuous bromegrass most increased the organic carbon content of the soil and the aggregate stability. There was no apparent effect of cropping system on soil pH, although there have been reports in the literature of acidification under legume cropping. Although nitrate in the soil profile tended to be higher under continuous legume than under other cropping systems, this finding was not reflected in total soil N analysis. The highest water infiltration rates were measured for soil under continuous grass treatment.

Conservation tillage. In a 4-year study, wheat grown under zero tillage yielded 1900 kg/ha compared with 1930 kg/ha under minimum tillage and 1840 kg/ha under conventional tillage methods on a Leith soil. Yields were comparable between zero, minimum, and conventional tillage on the Davis soil. However, yield of wheat increased significantly under zero tillage (1660 kg/ha) compared with minimum tillage (1450 kg/ha) and conventional tillage (1280 kg/ha) on a Boyer soil. Seeding with a hoe drill produced a wheat yield of 1880 kg/ha averaged over all locations and years, which was significantly higher than the wheat yield of 1530 kg/ha produced with the double disc drill.

Survey of trace elements in typical northwestern Alberta soils. There are few data available on the concentrations of extractable trace elements, including micronutrients such as boron and copper and toxic elements such as cadmium and lead, in typical soils of northwestern Alberta. The data generated in the present study are useful in at least two aspects: they provide a reference for evaluating soils in the region and a basis for the development of further soil micronutrient research; and they provide a background data base for evaluating soil pollution with metals such as cadmium and lead. The study is a collaboration between Agriculture Canada, the Alberta Research Council, and Alberta Environment. Fifty-two agricultural topsoil and 11 subsoil samples were extracted with DTPA, EDTA, water, and dilute HCl for trace metals. Boron was determined in mannitol-$CaCl_2$ extracts. Soil texture was found to be a suitable criterion for grouping soils in this region on the basis of their trace element status. Fine-textured soils were higher in silt and organic matter content than medium-textured soils (i.e. texture as coarse as or coarser than sandy clay). Fine-textured soils have higher concentrations of extractable boron, copper, zinc, cadmium, nickel, and lead than medium-textured soils. Trace element concentrations were well correlated with soil organic matter and generally better correlated with silt than with clay content. This survey indicates that of the micronutrients studied, boron is the one more likely to be deficient under certain cropping conditions, e.g., cropping a canola on a coarse-textured Gray Luvisol.

Types of soil crusting. Three morphological types of surface crusts were identified, including lamellar, sedimentational, and disruptional. Lamellar crusts were typical of soils high in clay and exchangeable Na and Mg. Sedimentational crusts were found in areas that were subject to large amounts of surface runoff and subsequent sedimentation of suspended materials. Disruptional crusts were formed by direct raindrop detachment of soil aggregates, subsequent disruption of aggregates, and a reduction of volume within the crust. Disruptional crust was the most common crust formed in the silty soils of the Peace River region. One characteristic, very common to all crust types, was the presence of layers 2–5 μm thick, within the immediate surface, that caused the complete sealing of the soil surface. The moisture content of the immediate surface layer determines the strength of the crust. Hence, water management and mulching are crucial for crust-prone soils.

Studies of organic matter in whole mineral soils by ^{13}C nuclear magnetic resonance (NMR) spectroscopy. Various preparation techniques for recording solid state ^{13}C NMR spectra of whole mineral soils were studied. Removal of paramagnetic mineral by a high-gradient magnetic separator improved the quality of ^{13}C NMR spectra of whole soil. Soil rich in organic matter and particle size fractions separated by a flotation technique also produced well-defined spectra. The C-to-Fe ratio appears to be an important indicator for obtaining satisfactory ^{13}C NMR spectra of whole soils and fractions separated from them. If the C-to-Fe ratio is $>>1$, the quality of the spectrum will be good; if the ratio is >1, a reasonable spectrum will be obtained, but if the ratio is <1, the spectrum will be poor.

Research Station, Beaverlodge, Alta.

Rhizobium strain identification and quantification. Analysis of commercial legume inoculants is carried out by Agriculture Canada as part of a regulatory program designed to maintain high quality in inoculants available to Canadian farmers. The inoculant analysis has been performed by growing the inoculants in plants, which requires 4 weeks to perform and is incapable of distinguishing between strains within a *Rhizobium* species. The advent of selected individual strains into the commercial market has created a need for rapid analysis at the strain level.

An immunoblot procedure for the strain-specific quantitative analysis of commercial *Rhizobium* inoculants was developed. The immunoblot procedure is rapid, strain-specific, and reliable. It requires only 4 days to complete, compared with 4 weeks for the nodule grow-out method of inoculant analysis. The grow-out test does not determine strain identity, whereas the membrane immunoassay checks strain identity of all colonies on a plate. Some commercial legume inoculants contained as many contaminants as *Rhizobia*. Nevertheless, it was possible to analyze contaminated products for *R. meliloti* NRG 185 and Balsac. Correlation between immunoblot analysis and traditional plant bioassay techniques was $r = 0.90$ for 16 commercial alfalfa inoculants tested.

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[1] On educational leave effective 19 August 1986.

INTRODUCTION

The Lacombe Research Station and the Soils and Crops Substation at Vegreville are responsible for regional agricultural research in the central Alberta parklands. Specifically, programs include soil reclamation and development of cropping practices for Solonetzic soils of east-central Alberta; breeding new, high-yielding, disease-resistant oat and hard red spring wheat (replacement for Park) cultivars for domestic use and for export; and developing soil fertility, soil management, weed control, and cropping systems for barley, oat, and canola production in the parklands. The station has regional responsibility for production and disease research of perennial forage crops; development and evaluation of hay management systems that will improve the quality of stored forages; and development of management systems and evaluation of new forage species and plant growth regulators to extend the pasture season, all of which will be used by beef and dairy farmers to optimize milk and beef production per hectare. The mandate of the Lacombe Research Station also includes research responsibility for regional and national programs in red meats, with integrated supporting programs in pork and beef production that include developing and evaluating various muscle types of meat animals; assessing the effect of nutrition, management, and environmental stress on growth, performance, and subsequent carcass quality; and conducting research to support technical aspects of the beef cattle and swine record of performance (ROP) testing programs. The red meats research includes developing and evaluating new procedures and techniques for improving the effectiveness of national departmental beef and swine carcass grading programs. The research also involves work on the physical, chemical, microbiological, and sensory aspects of beef and pork quality in relation to preslaughter and postslaughter environmental conditions, processing systems, and carcass management, both at the meat-packing plant and at the retailer level, and with consideration given to cooking quality and other factors related to consumer acceptance of the final product.

This report summarizes the highlights of research completed in 1988. Further information on any of these research activities, reprints of publications listed in this report, and copies of previous reports may be obtained from the Research Station, Research Branch, Agriculture Canada, Bag 5000, Lacombe, Alta. T0C 1S0; Tel. (403) 782-3316.

D.E. Waldern
Director

RED MEATS AND BEEF PRODUCTION

Beef production

Postweaning gain and efficiency of crossbred calves from Charolais, Simmental, and Limousin sires mated to Hereford, Angus, and Shorthorn dams. Research conducted at the Lacombe and Brandon research stations has provided several comparisons of feedlot growth and efficiency involving calves sired by Charolais, Simmental, or Limousin bulls and born to Hereford, Angus, or Shorthorn dams. Breed comparisons have been made using data derived over a period of 4 years from bull, steer, and heifer calves born in 48 beef herds in the Canadian prairie provinces. The calves were reared on pasture with their dams. Following weaning, half the male calves were castrated, and the bull and steer calves were placed on a high-energy feeding program to gain 1.0–1.7 kg/day. Heifer calves were fed a lower energy rearing diet.

Charolais-sired steers gained an average of 14.0 kg more liveweight than Limousin-sired steers from comparable dams in a 112-day test period (125 g/day). Simmental-sired bulls and steers exceeded Limousin-sired bulls and steers from comparable dams by an average of 9.6 kg (86 g/day). There were, however, no corresponding differences in feed conversion ratio. Limousin-sired heifer calves also tended to achieve lower rates of growth than those sired by the other two breeds, but the effect was much less apparent than for male calves, possibly because the heifer calves were on a lower energy diet. The growth rates of calves from Hereford, Angus, and Shorthorn dams did not differ in a consistent manner in this 112-day test.

The effects of fasting and transportation on beef cattle: body component changes, carcass composition, and meat quality. Fifty Hereford cattle (30 steers, 20 heifers) that had been fed a cereal and silage diet ad libitum were assigned to three treatments on the basis of liveweight within sex. Treatment 1 animals were not mixed with unfamiliar animals, were fasted for 24 h, and were slaughtered. Treatment 2 animals were initially fasted for 24 h, mixed, transported for 320 km, and held in lairage until total time off feed reached 48 h. Treatment 3 animals were fasted for 24 h, mixed, transported for 320 km on 2 consecutive days, and held in lairage until total time off feed reached 72 h. All animals had access to water up to the time of slaughter except during transportation. Liveweight was recorded at the start of the trial, on return from transportation, and immediately before slaughter. Liveweight shrinkage amounted to 17, 45, and 53 g/kg for treatments 1, 2, and 3 respectively. The primary components involved in this loss for treatment 2 and 3 animals were warm carcass weight (10 and 15 g/kg), gutfill (10 and 15 g/kg), and body fat depots (0.3 and 8 g/kg). Body organs, including the liver, showed only minor proportional changes with longer fasting. The proportion of lean and fat in the loin and hip of carcasses was similar for all treatments. Treatment had no effect on muscle pH (45 min and 24 h), expressible juice, muscle fat content, or weight losses of steaks during retail display. Meat color for both the loin eye muscle at 24 h and for retail steaks was significantly darker in treatments 2 and 3 compared with treatment 1, but the change was not of sufficient magnitude to result in dark, firm, and dry meat. The main effect of fasting and transportation in beef cattle was concluded to be a loss in carcass weight and gutfill.

Carcass grading

The effect of genotype on predicted lean yield in heavy pig carcasses using the Hennessy Grading Probe and the Destron PG-100 electronic grading probe. The background work used to develop an electronic hog carcass grading system was based on commercial carcasses largely composed of the white breeds (Yorkshire, Landrace) and their crosses, but did not consider the extent of bias in predicted lean yield, which might be attributed to differences among conformation and muscularity in other breed types, or the application to the prediction of lean yield in heavy (>80 kg) pork carcasses. This study was conducted to examine the appropriateness of existing equations to predict lean yield from probe measurements on heavy carcasses. The study also examined the extent to which the prediction of lean yield is influenced by the genotypes and the body conformation of the pig. Carcasses from four genotypes (LAC, Lacombe; HSL, a Lacombe-based, halothane-positive line; XBD, a LAC × HSL F_1 cross; and YRK, Yorkshire. These four genotypes ranged from 73 to 104 kg and were evaluated by two electronic grade probes, Hennessy Grading Probe (HGP) and Destron PG-100 (DGP). The genotypes were then physically separated into lean, fat, and bone according to the *Agriculture Canada Livestock and Poultry Production Division Pork Carcass Cutability Specification Guide*.

As pigs became heavier, their dressing percentage increased, but the lean yield of their carcass decreased. Furthermore, the HSL line had 4% greater dressing percentage and 4.5% greater lean yield than did Lacombe pigs, which did not carry the halothane gene. Progeny from the cross of these two lines (i.e., halothane carrier pigs) were intermediate to their parental lines, as expected from our understanding of the inheritance of the halothane gene. The Yorkshire pigs also had a greater dressing percentage and lean yield compared with that of the Lacombe pigs but not as high as in the HSL pigs.

The average predicted lean yield was 0.2% higher for the HGP than for the DGP but fell within the established tolerance levels specified for electronic grading probes. However, as carcass weight increased, both probes progressively underestimated actual lean yield. Lean yield in carcasses in excess of 100 kg was underestimated by 1.8%. However, at present this does not represent a serious problem for the current grading of pork carcasses because relatively few carcasses in excess of 90 kg are marketed. Both probes underestimated lean yield in HSL and YRK but overestimated lean yield in LAC. The most serious bias was recorded for HSL, which has a short, thickly muscled carcass. There are relatively few pigs with a conformation similar to the HSL pigs in the current Canadian population, and so this result would not currently have much commercial significance. However, the trend for increased use of terminal sire lines with similar characteristics

to the HSL line has occurred in Europe and may be a future development in the Canadian swine industry.

The effect of preslaughter feed restriction and genotype for stress susceptibility on lean quality and composition of pork. The effect of the duration of feed restriction before slaughter on the ultimate lean meat quality of the *longissimus dorsi* muscle (loin eye) was tested in three lines of pigs of differing genotypes with respect to stress susceptibility. Pigs of the Lacombe breed (genotype NN), none of which has been shown to be halothane-positive, yielded essentially no (0–4%) pale, soft, exudative pork at any of the three feed restriction treatments (0, 24, and 48 h off-feed). The meat quality of pigs from the halothane-positive line (genotype nn) was altered dramatically by the off-feed treatment. The incidence of pale-colored pork decreased from 57% at 0 h off-feed to 9% at 48 h off-feed, and the incidence of soft, exudative pork decreased from 87% at 0 h off-feed to 48% at 48 h off-feed. NN × nn crossbred pigs (genotype Nn), all of which gave a negative response to the halothane test, were intermediate in quality between the other two genotypes at all times off-feed. In no instance did the feed restriction treatment produce dark, firm, dry (DFD) meat. These data suggest, first, that halothane-negative carriers of the halothane gene may contribute considerably to the incidence of pale, soft, exudative (PSE) pork and secondly, that manipulation of the length of time off-feed before shipping for slaughter may offer potential as a management practice to improve meat quality.

Postmortem technology

The effects of spray-chilling beef carcasses on the shrinkage and quality of beef. After slaughter, alternate beef carcass sides (left, right) were allocated to an intermittent spray-chilling cooling treatment using water (four cycles per hour; 60 s per cycle) and conventional air chilling (1–2°C; air velocity 0.5 m/s) or conventional air chilling only. Experiments 1, 2, and 3 (n = 19, 16, and 16 carcasses) involved spray-chilling for 4, 8, 12 h in shrouded sides, whereas experiment 4 (n = 16 carcasses) examined 8 h of spray-chilling in unshrouded sides. At 24 h postslaughter all sides were ribbed between the 12th and 13th rib and assessed for meat and fat color. Half the treatment and control sides in each experiment were aged for 6 days, while the boneless ribs and inside rounds were removed from the remaining sides, vacuum packaged, and held for 6 days. After 6 days of storage, retail packs of rib steaks and round roasts were prepared and assessed for color and drip losses over a 4-day period. Spray-chilling significantly reduced carcass shrinkage at 24 h postslaughter in experiments 1–4 by 0.48, 0.69, 0.89, and 1.43%, respectively. After 6 days of cooler storage, spray-chilling significantly reduced carcass shrinkage in experiments 3 and 4 only (0.47 and 0.94%). Weight and drip losses for vacuum-packaged ribs and inside rounds were not influenced by spray-chilling over 6 days of storage. Spray-chilling had no influence on rate of pH decline, but reduced loin and round muscle temperatures by 1–2°C. Loin eye muscle color and shear force were not affected by treatment, but in experiments 2, 3, and 4, fat color was significantly lighter in spray-chilled compared with conventionally chilled sides. Color changes and drip losses in retail packs over 4 days for rib steaks and round roasts were not related to spray-chilling. It was concluded that spray-chilling could provide a moderate reduction in carcass shrinkage during cooling without having a detrimental influence on muscle quality.

Meat microbiology

Effects of quality of pork muscle on bacterial growth and retail case life. Stress-related aberrations in quality of pork muscle include pale, soft, and exudative (PSE) and dark, firm, and dry (DFD). In comparison to pork of "normal" muscle quality, PSE pork is characterized by a lower pH, reduced water-holding capacity, and a paler color, whereas DFD pork has a higher pH, greater water-holding capacity, and a darker color.

In view of these pronounced physicochemical differences, the current work was designed to determine the effects of muscle quality (PSE, normal, DFD) on the bacteriology and retail case life of pork chops. Pork loin chops were processed from boneless backs after 90 days of frozen storage at −30°C. Variation in bacterial numbers was due to a highly significant ($P < 0.001$) storage time by muscle-quality interaction. During simulated retail display, total psychrotrophs, *Pseudomonas* spp., *Brocothrix thermosphacta*, and Enterobacteriaceae were lowest on PSE pork and highest on DFD pork in comparison to that of normal pork. Differences in bacterial densities were due to a longer lag phase on PSE pork and

a shorter lag phase on DFD pork than on normal pork. Of the three muscle-quality groups, DFD was most susceptible to the development of spoilage odors, whereas PSE pork was most sensitive to deterioration in appearance. It would appear that the sensitivity of PSE pork to discoloration is due to a nonbacterial chemical denaturation, whereas the development of spoilage odors more closely reflects bacterial growth and metabolism.

Sensory evaluation

A comparison of flavor and texture profiles for lamb leg roasts from three different geographical sources. Lamb leg roasts from Canada required less time to reach 75°C internal temperature than roasts from Australia or New Zealand and sustained lower total cooking losses than roasts from Australia ($P < 0.05$). In addition, complete flavor and texture profiles compiled from the evaluation of 60 fresh (unfrozen) legs of lamb (20 from Australia, 20 from Canada, and 20 from New Zealand) revealed that both Australian and New Zealand lamb generally rated higher ($P < 0.05$) than Canadian lamb in textural traits not directly related to tenderness and that New Zealand lamb generally rated higher ($P < 0.05$) in textural traits directly related to tenderness than did Canadian lamb. They also revealed that Australian lamb had the most intense lamb flavor ($P < 0.05$) and that Canadian lamb was perceived to contain the most fat. In addition, fishy and metallic notes were most intense ($P < 0.05$) and occurred most frequently ($P < 0.05$) in New Zealand lamb, whereas a livery note was most intense and occurred most frequently ($P < 0.05$) in Australian lamb. It should be noted, however, that in the present study differences in flavor and texture amplitude or general impression were not detected as a result of differences in geographical source ($P > 0.05$).

PLANT AND SOIL SCIENCE

Forage crops

Mefluidide effects on yield and quality of smooth bromegrass. Smooth bromegrass is adapted to the Parkland of the Canadian prairies, where it is used extensively as hay and pasture. However, forage quality of smooth bromegrass deteriorates rapidly as the stems elongate and seed heads appear. In addition, initial tillers represent 60–70% of seasonal dry matter by anthesis. The lack of late-season growth limits its carrying capacity as a pasture grass. To alleviate these problems the plant growth regulator mefluidide was applied to smooth bromegrass at 150 and 300 g/ha before jointing (early May) over a period of 2 years. The following were measured: yield and quality at three stages of initial growth (preboot, anthesis, and hard dough); and yield, yield distribution, and quality of a three-cut system beginning at the preboot stage. Compared with the control, the mefluidide at a rate of 300 g/ha was most consistent in effecting change. Yield was reduced by mefluidide to 32, 66, and 85% of the control at the preboot, anthesis, and hard dough stages of initial growth. Total yield over the three-cut system was reduced by 17%, although yield distribution was improved. The improved yield distribution occurred because of the reduction in preboot yield and a yield increase to 400% of the control at the second cut. Unfortunately, no improvement in forage yield occurred late in the year (cut 3) as a result of mefluidide treatment. Forage quality was improved uniformly over all initial cuts but decreased at the second cut of the three-cut system. Differences in forage quality among treatments were attributed to corresponding differences in leaf-to-stem ratio. Crude protein and in vitro digestibility (IVD) increased, whereas neutral (NDF) and acid (ADF) detergent fiber, lignin, and cellulose decreased slightly over initial stages of growth. IVD decreased, whereas NDF, ADF, and cellulose content increased with mefluidide application at cut 2 of the three-cut system. The improved forage quality of initial growth would be advantageous for hay production in smooth bromegrass. An improved yield distribution shown in the frequently cut regime, as a result of mefluidide, may be advantageous in pasture systems. Whether the improvement in forage quality, caused by mefluidide, will follow through to animal performance must be studied in further experiments with mefluidide.

Cereal physiology

Plant hormones in hardening winter wheat. During over-wintering in a northern climate, winter wheat goes through a hardening process, followed by de-hardening in late winter–early spring. This sequence of events may be partly controlled by changes in endogenous hormone levels. Crowns and leaf tissue

from field-grown winter wheat plants (cultivar Norstar) was collected and freeze-dried at monthly intervals following seeding at the beginning of September. Material was also sampled and freeze-dried from seedlings grown in a growth chamber under hardening conditions (21°C for 2 weeks plus 3°C for 6 weeks) or nonhardening conditions (3 weeks at 21°C). The tissue was analyzed for abscisic acid (ABA), an inhibitory plant hormone known to be involved in the hardening response, and cytokinins, plant hormones generally involved in active growth and dormancy release. Cytokinin levels declined from October onward and then rose to a peak in late winter (February), subsequently declining again. Nonhardened crown tissue from the growth chamber contained more than double the cytokinin activity of hardened tissue. ABA levels in the crowns of the field-grown winter wheat seedlings initially increased from October to November, then decreased to a relatively low level between December and April, and finally increased in March to a level similar to the October sampling period. Leaf tissue from seedlings hardened in a growth chamber contained more than double the ABA activity of nonhardened leaf tissue. In terms of hardiness, the winter wheat reached its maximum frost resistance in November, declined to a somewhat less resistant condition over December to February, and then declined much more rapidly thereafter. The results suggest that ABA and cytokinins act in an opposite manner during the hardening process. ABA does not appear to act on the long-term maintenance of coldhardiness but may function more as an inducer of hardiness. The cytokinin peak in late winter occurs just before a relatively sharp decline in frost resistance and this increase in growth-promoting hormone may signal the end of the most resistant period preparatory to the resumption of active growth.

Cereal pathology

Snow molds of winter wheat in central and northern Alberta. A major limitation to winter wheat production in the parklands of the Canadian prairies is the periodic failure of this crop to survive the winter. The snow cover that usually remains on the land all winter in the parklands provides a thermal blanket against the lethal, low soil temperatures, and the sufficient level of coldhardiness in the cultivar Norstar suggests that snow molds are the most probable cause of the failure of winter cereals to survive the winter. Extensive surveys of fields of winter wheat and rye in central and northern Alberta in the spring of the years 1985–1987 indicated that the snow mold *Coprinus psychromorbidus* was the most frequently isolated pathogen on winter wheat and rye that died during the winter. This pathogen is also found on legumes and grasses, and winter wheat seeded immediately after breaking pasture often has been shown not to survive the winter because of an attack by *C. psychromorbidus*. A test was established at Lacombe to determine the longevity of inoculum of *C. psychromorbidus* in the soil under spring wheat and canola. The inoculum of *C. psychromorbidus* was applied in the fall to plots of winter wheat. None of the inoculated winter wheat survived the first winter. The following spring the plots of dead winter wheat were cultivated and sown to spring wheat and canola. These crops were not affected by the snow mold. The test was designed in such a way as to replant winter wheat 1, 2, 3, 4, and 5 years after the initial application of *C. psychromorbidus*, and spring wheat and canola were planted during the intervening years. Winter wheat failed to survive for up to 3 years after the initial introduction of the *C. psychromorbidus* inoculum into the soil, but winter wheat did survive in the fourth year, suggesting that the inoculum may survive in the soil for a period of 3 years. Farmers should therefore avoid sowing winter wheat and rye on land where these crops were winter-killed by this snow mold or on grass pastureland for 3 years.

Weed research

The effects of imazamethabenz on wild oat, green foxtail, and Tartary buckwheat. Imazamethabenz is a selective postemergence herbicide recently registered for use on cereals (spring wheat, spring barley, and durum wheat). The herbicide controls wild oat in the one-to-four-leaf stage as well as stinkweed and wild mustard in the cotyledon-to-six-leaf stage. In addition, imazamethabenz suppresses wild and Tartary buckwheat, and seems to have minor effects on green foxtail. Imazamethabenz exhibits good crop tolerance, can be tank-mixed with 2,4-D and 4-chloro-2-methylphenoxyacetic acid (MCPA), and performs well under dry conditions.

Research Station, Lacombe, Alta.

Field experiments were conducted over 2 years with Neepawa wheat and Galt barley, with wild oat planted between the crop rows. Imazamethabenz was applied to the wild oat in the two- and four- leaf stages with a motorized small-plot sprayer in 100 L of water per hectare. Greenhouse studies that included green foxtail and Tartary buckwheat were also conducted.

Imazamethabenz gave good wild oat control over normal rates of use (0.3–0.5 kg/ha). Those rates reduced the fresh weight of wild oats to at least 20–30% of the untreated checks. Considering the rather dry conditions that prevailed during the experiments and the fact that the results are averaged over treatment at two growth stages (two- and four-leaf wild oat) and 2 years, control of wild oat was excellent. Imazamethabenz suppressed both green foxtail and Tartary buckwheat. At the above rates of use, green foxtail fresh weights ranged from 55 to 80% of untreated checks, whereas Tartary buckwheat fresh weights ranged from 30 to 40% of untreated checks.

In summary, Imazamethabenz controlled wild oat, suppressed Tartary buckwheat, and slightly suppressed green foxtail.

Soil fertility

Recovery of ^{15}N-labeled urea and potassium nitrate as influenced by date of application. In the Prairie Provinces, N fertilizers are often applied in fall rather than in spring for spring-sown cereal grain crops. In some areas, fall-applied N fertilizers, at least when broadcast and incorporated into the soil, are often less effective than spring-applied N in increasing crop yields. Ammonium-based fertilizers are superior to nitrate-based fertilizers with fall application for barley in north-central Alberta. Rate of nitrate formation from ammonium is related to soil temperature. Therefore, early fall application would be expected to form more nitrate during the fall and winter period than the late fall application, and subsequently to incur more N loss over the winter. Field experiments were conducted during 1982–1983 at two sites (Breton, in north-central Alberta, and Innisfail, in central Alberta) to determine the recovery in barley plants and soil of ^{15}N-labeled urea and potassium nitrate, with N applied at a rate of 50 kg/ha. Dates of application were early October, late October, late winter, and spring.

Recovery of ^{15}N in soil samples taken before sowing in the spring of 1983 indicated N losses over the winter from October-applied N at both locations and especially with potassium nitrate. At Breton, spring recovery of ^{15}N in soil from the October application was 69% with urea and 30% with potassium nitrate. Late-winter application had nearly complete spring recovery in the soil for urea (96%), but the recovery remained low for potassium nitrate (31%). The amount of ^{15}N immobilized in the soil was greater with urea than potassium nitrate for both sites. ^{15}N applied in the fall or late winter was not detected any deeper than the 15–30 cm layer of soil in spring at the Innisfail site, but small amounts were found in the 55–70 cm depth at Breton. Therefore, the mechanism of N loss was caused primarily by denitrification. The total recovery at harvest (plants plus soil) of ^{15}N fertilizer applied in October or late winter was low, with a range of 7–71%. Application in the spring generally gave higher total recovery of ^{15}N at harvest, but varied with location and N source. Specifically, values at Innisfail were 88% for urea and 84% for potassium nitrate, but at Breton, which had heavy rain and saturated soil in early July, recovery was lowered with urea (56%) and lowered more with potassium nitrate (10%). In all, losses of ^{15}N occurred in the noncropped period over the winter and during the cropped season. The ^{15}N recovery was less with fall compared with spring application and the recovery was less with potassium nitrate compared with urea.

SOILS AND CROPS SUBSTATION VEGREVILLE

Solonetzic soils

Improvement of Solonetzic soils by nitrogen and calcium amendments. Solonetzic soils occupy nearly 4 million ha in Alberta, with lesser areas in Saskatchewan and Manitoba. Research on methods to improve crop production on Solonetzic soil has been conducted since the mid 1950s by Agriculture Canada at the Vegreville Soils and Crops Research Substation. The Ap horizon of a Solonetzic soil is generally shallow, acidic, and coarse-textured. The Bnt horizon is sodic, alkaline, and poorly structured. This results in poor water infiltration, aeration, and rooting-depth restrictions. Amelioration techniques must improve the condition of the Bnt horizon while minimizing any negative effect on the Ap horizons.

This study was intended to determine what interaction may occur between surface application of calcium minerals with shallow incorporation and broadcast application of ammonium nitrate. Combinations of treatments were used to test three rates of nitrogen and six sources or rates of calcium minerals. The calcium minerals were incorporated on 7 October 1982. Barley was grown for 3 years on this site. One of the 3 years was relatively wet, and 2 years had nearly drought conditions. In 2 of the 3 years, a significant response of grain yield to nitrogen occurred.

Nitrogen fertilization with N at a rate of 50–100 kg/ha resulted in significant increases in yield of barley from 4.7 Mg/ha and 1.9 Mg/ha to 5.2 Mg/ha and 2.5 Mg/ha in both a wet year (1986) and a dry year (1988), respectively. The addition of calcium minerals also significantly increased barley yield in a moist year (1986) and tended to increase yield in 1988, which was dry until a storm in June. Growing season precipitation has an effect on both the total yield and on the applied treatments. In 1987 no significant yield difference occurred, and there was a trend toward yield reduction resulting from nitrogen fertilization. In 1988 significantly higher yields occurred because of N fertilization, and there was a trend toward increased yield resulting from calcium additions. Although 1988 had above-average precipitation, there was significant drought in April and May, with 47 mm of rain from a storm on 8 June. This early drought limited total yield, but yield responses to treatments occurred because of improved moisture conditions later in the season.

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H.H. Mündel, B.S.A., M.S., Ph.D.	Safflower, corn breeding
G.A. Nelson, B.Sc., M.Sc., Ph.D.	Potato and bacterial diseases
R.S. Sadasivaiah, B.Sc., M.Sc., Ph.D.	Soft white spring wheat breeding
B.D. Schaber, B.Sc., M.Sc., Ph.D.	Forage crop pests
D.L. Struble, B.A., M.A., Ph.D., F.E.S.C.	Insect attractants

J.B. Thomas, B.Sc., M.Sc., Ph.D.	Winter wheat breeding
E.D.P. Whelan, B.S.A., M.S.A., Ph.D.	Wheat cytogenetics
W.D. Willms, B.S.F., M.Sc., Ph.D.	Rangeland ecology

Livestock Sciences

G.H. Coulter, B.S.A., Ph.D.	Head of Section; Reproductive physiology
R.W. Baron, B.Sc., Ph.D.	Assistant Section Head; Immunology
C.B.M. Bailey, B.S.A., M.S.A., Ph.D.	Ruminant physiology
D.R.C. Bailey, B.Sc., Ph.D.	Beef cattle breeding
K.A. Beauchemin,[11] B.Sc., M.Sc., Ph.D.	Ruminant nutrition
K.-J. Cheng, B.Sc., M.Sc., Ph.D.	Rumen microbiology
D.D. Colwell, B.Sc., M.Sc.	Cattle grub ecology
T.J. Danielson,[12] B.S.P., Ph.D.	Toxicology
B.S. Freeze, B.S.A., M.Sc., Ph.D.	Bioeconomist
T.W. Hall,[13] B.Sc., Ph.D.	NMR spectroscopy
R. Hironaka,[14] B.Sc., M.Sc., Ph.D.	Ruminant nutrition
L.A. McClelland, B.Sc., M.Sc.	Sheep production
G.J. Mears, B.Sc., M.Sc., Ph.D.	Ruminant physiology
R.C. Phillippe, B.Sc.	Rumen bacteriology
L.M. Rode, B.S.A., M.S., Ph.D.	Ruminant nutrition
J.A. Shemanchuk, B.Sc., M.Sc., C.D., F.E.S.C.	Biting-fly ecology
W.G. Taylor, B.S.P., Ph.D.	Pesticide chemistry

Soil Science

C.W. Lindwall, B.Sc., M.Sc., Ph.D.	Head of Section; Conservation tillage
J.F. Dormaar, B.S.A., M.S.A., Ph.D.	Assistant Section Head; Organic chemistry
J.R. Allan, B.Sc., M.A., Ph.D.	Aquatic plant physiology
G.J. Beke, B.S.A., M.Sc., Ph.D.	Hydrology
J.M. Carefoot, B.S.A., M.S.A., Ph.D.	Irrigation agronomy
C. Chang, B.Sc., M.Sc., Ph.D.	Soil physics
N. Foroud, B.Sc., M.Sc., Ph.D.	Irrigation engineering
B.W. Grace,[15] B.Sc., M.Sc., Ph.D.	Agrometeorology
M.F. Hynes, B.Sc., M.Sc., Ph.D.	Microbial genetics
H.H. Janzen, B.S.A., Ph.D.	Dryland agronomy
R.M.N. Kucey, B.Sc., Ph.D.	Soil microbiology
S.M. McGinn,[16] B.Sc., M.Sc., Ph.D.	Agrometeorology
B.M. Olson,[17] B.S.A., M.Sc., Ph.D.	Biochemistry
T.G. Sommerfeldt, B.Sc., M.S., Ph.D.	Drainage engineering
C.A. Webber,[18] B.Sc., M.Sc.(Comp.Sci.), M.Sc.(Ag.Ec.)	Bioeconomics

Onefour Substation

A.G. Ross	Farm Manager

Vauxhall Substation

B.C. Farries	Farm Manager

Departures

D.G. Dorrell, B.S.A., M.Sc., Ph.D. Transferred to Western Region Headquarters, October 1988	Director

M.R. Hanna, B.S.A., M.S.A., Ph.D. Retired June 1988	Forage legume breeding
J.E. Lawson, B.S.A., M.S.A. Retired November 1988	Beef cattle breeding
M.D. MacDonald, B.Sc., Ph.D. Retired June 1988	Corn breeding

VISITING SCIENTISTS

M.E. Leggett, Ph.D., Philom Bios, February 1987–June 1989	Phosphate solubilization
R.P. Gilbert, Ph.D. Research associate, NSERC fellow, November 1988–November 1989	Beef cattle breeding

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1 Appointed March 1988.
2 Appointed April 1988.
3 Seconded from Libraries Division, Finance and Administration Branch.
4 Appointed August 1988.
5 On educational leave, North Carolina State University, N.C., August 1985–August 1988.
6 On transfer of work, Rothamsted Experimental Station, England, February 1987–February 1988.
7 Appointed September 1988.
8 Seconded to Pesticides Directorate, Ottawa, November 1987–March 1989.
9 Appointed December 1988.
10 On transfer of work, INRA station de bioclimatologie, Montfavet, France, August 1987–August 1988.
11 Appointed September 1988.
12 Appointed June 1988.
13 Appointed October 1988.
14 Seconded to Priorities and Strategies Directorate, Research Branch, May 1987–April 1988.
15 Seconded to CIDA, Arusha, Tanzania, July 1988–July 1990.
16 Appointed October 1988, 2-year term.
17 Appointed August 1988, 2-year term.
18 Appointed May 1988.

INTRODUCTION

The research station at Lethbridge, in southern Alberta, is located at the centre of one of the most diverse agricultural regions in Canada. A variety of crops is grown on both dry and irrigated land, and a major part of Canada's beef cattle industry is established on the farms and ranches within and around the region.

Station scientists conduct fundamental and applied research in support of 12 Research Branch objectives. In addition to the 500-ha site at Lethbridge, the station conducts research at a 17 000-ha beef cattle ranch near Manyberries, a 400-ha ranch near Stavely in the foothills of the Rocky Mountains, and a 130-ha irrigation substation at Vauxhall. Fundamental and applied research focuses on plant breeding; the control of plant diseases, weeds, and insect pests; soil fertility, tillage, and water use; and livestock improvement, nutrition, and the control of livestock pests.

Crop production and improvement research deals with the breeding and genetics of 10 different species or crop kinds, the study of the biology and control of a wide range of plant diseases and insect pests, and the development of improved agronomic practices related to soil fertility, tillage, and water use. Related studies on physical, chemical, microbiological, and hydrological aspects of soil provide guidance for the introduction of methods to maintain or improve the soil resource.

Livestock research is concerned with evaluating the effects of breed or selection methods on the improvement of beef or dairy cattle, and of breed and management on sheep productivity. Other studies on nutrition, rumen microbiology, and physiology contribute to the development of efficient methods of beef and dairy cattle production. The station is also a major centre for the study of arthropod pests of livestock.

Several changes in staff and organization occurred at the station during 1988: Dr. D.G. Dorrell, director, was appointed director general, Western Region, Agriculture Canada, located in Ottawa; Dr. P.A. O'Sullivan was named acting director; and Dr. D.L. Struble was named acting assistant director. In the Livestock Sciences Section, Mr. J.E. Lawson retired; Dr. G.H. Coulter was appointed section head; and Dr. R.W. Baron was appointed as assistant section head. Three new scientists joined the section: Dr. K.A. Beauchemin (ruminant nutrition), Dr. T.J. Danielson (toxicology), and Dr. T.W. Hall (NMR spectroscopy). In the Soil Science Section, Dr. J.F. Dormaar was appointed assistant section head, and Mr. C.A. Webber (economist) joined the section. Two new term scientists were appointed in the section: Dr. S.M. McGinn (agrometeorology), as a replacement for Dr. B.W. Grace, who accepted a 2-year Canadian International Development Agency assignment in Tanzania; and Dr. B.M. Olson (soil biochemist). Two scientists retired from the Crop Sciences Section: Dr. M.R. Hanna (forage breeding) and Dr. M.D. MacDonald (corn breeding), and two new scientists joined the section: Mr. R.A. Butts (toxicology) and Dr. M.S. Goettel (insect pathology). In the Scientific Support Section, Mr. W.A. Conrad joined as computer systems manager and Mr. R.W. McMullin as technology transfer officer. Mr. W.H. Marshall transferred from the Beaverlodge Research Station as the administrative officer—finance and materiel management.

Our scientists hosted visiting scientists and foreign delegations; and participated on graduate students' thesis committees, international secondments, and exchanges. They also served on numerous provincial, national, and international committees. Several of our clients participated directly in our research activities; Farming for the Future of Alberta Agriculture partially funded 13 projects, the Western Grains Research Foundation funded three projects, and new collaborative research was initiated with several companies.

This report gives results of some recent research and illustrates the types of studies that are under way. Further information may be obtained from publications listed at the end of the report or from our scientists. Correspondence or requests for reprints should be addressed to the Director, Research Station, Research Branch, Agriculture Canada, Lethbridge, Alta. T1J 4B1; Tel. (403) 327-4561; Fax (403) 382-3156.

P.A. O'Sullivan
Acting Director

CROP SCIENCES

Field crop diseases

Elimination of ring rot by in vitro culturing. The incidence of bacterial ring rot (*Corynebacterium sepedonicum*) in a potato breeding program would result in a serious loss of potentially valuable clones and may require that all materials in the program be discarded. The hazard is considerably enhanced by genotypes that do not readily develop visible symptoms and by the fact that, even in susceptible genotypes, small numbers of ring rot bacteria could possibly remain undetected through several generations of tubers. In a 3-year study, an in vitro technique was developed to free potato clones from ring rot. Tuber eyes, confirmed to be infected with ring rot by Gram stain and development of visible symptoms, were freed from the ring rot bacteria by the in vitro culturing of 4 mm of apical tissue derived from sprouts 4 cm long. The success of this procedure is probably associated with the lack of well-developed vascular tissue in the explant. This technique provides breeders with a rapid, inexpensive method of ensuring that advanced clones are free from ring rot bacteria prior to large-scale multiplication.

White mold. A field survey conducted during 1983–1987 revealed that white mold caused by *Sclerotinia sclerotiorum* is the most serious disease of pulse and oilseed crops such as field beans, canola, and sunflower in southern Alberta. The pathogen produces black sclerotial bodies that overwinter in the soil, and it can cause two distinct diseases on host crops, root rot or wilt and stem canker or head rot, depending upon the mode of sclerotial germination. Root rot or wilt is caused by soilborne infection by mycelia from the myceliogenic germination of sclerotia, and stem canker or head rot is caused by airborne infection by ascospores from the carpogenic germination of sclerotia. The infection of field bean, canola, and safflower is produced mainly by airborne ascospores but the infection of sunflower can result from both soilborne mycelia and airborne ascospores. Results of a fundamental study showed that myceliogenic germination of sclerotia was triggered by injury or incomplete melanization of the rind tissue and that only fall melanization would impede myceliogenic germination and foster dormancy of sclerotia. This study has provided a further understanding on the epidemiology of *Sclerotinia* wilt in field crops.

Forages

Sainfoin pollinators. The density and efficiency of bumble bees, honey bees, and alfalfa leafcutter bees on sainfoin grown in southern Alberta were studied. Six species of bees were identified as pollinators, with alfalfa leafcutter bees comprising 56% of the observations, honey bees 40%, and bumble bees 4%. The density of flowers over the season can be described as curvilinear. The mean number of flowers per raceme decreased significantly over the season. The rate of foraging by pollinator species from flower to flower varied and was described by multiple regression models. Julian date, hour of day, and flower density are the independent variables. More than 90% of the bees visited three or fewer flowers per raceme when 60% of the racemes had three or more flowers available for pollination. The bees foraged on sainfoin for about 12 h per day and the average density of bees increased significantly with the corresponding density of flowers. A theoretical approach used to predict the bee populations required to pollinate varying flower densities shows that the required population of bumble bees is about two-thirds that of honey bees or alfalfa leafcutter bees. The observed populations of pollinators did not correspond well with the derived values, probably because multiple visits per flower are required for fertilization.

Sainfoin seed chalcid. The seasonal occurrence of adults and larvae of the sainfoin seed chalcid, *Eurytoma onobrychidis* Nikolskaya, infesting pods of sainfoin was determined. Sainfoin pods were infested and female chalcids were present throughout the flowering period. The proportion of pods infested varied each year. A parasitic chalcid, *Habrocytus medicaginis* Gah., attacked a low percentage of pods infested with seed chalcids. The time necessary for postdiapause, overwintering larvae to defecate, pupate, deposit pigment, and emerge as adults was influenced by temperature and differed by sex. Sainfoin adults emerged at least 3 weeks before flowering began, thus providing time to implement control. Larvae in infested pods subjected to cold treatment (–40°C for 5 days) immediately after harvest were killed, and seed germination was not hindered by the cold treatment.

Research Station, Lethbridge, Alta.

Nutritional value of dandelions. In forage crops all plants are either harvested and combined into hay or available for grazing by animals. Dandelions often contribute 10% or more of the total forage produced on pastures but the degree of utilization by animals is unknown. A grazing study was conducted with Hereford cows over three grazing periods in 1 year on an orchardgrass pasture containing 10% dandelion (based on dry matter yield). The percentage of available plant material consumed was equal or greater for dandelion than for orchardgrass. Protein contents were similar in dandelion and alfalfa but acid detergent fiber was lower in dandelion than in alfalfa. The concentration of Ca, P, Mg, K, Cu, Zn, Mn, and Se in dandelions and orchardgrass was determined, and the mineral contents of both were high enough to meet the established requirements of cattle. In previous studies, dandelions did not reduce the total forage yield in orchardgrass pastures. Thus, herbicide use for dandelion control could be reduced.

Other cereals

Nonreplicated yield testing for cereals. The large number of lines or selections and the small quantity of seed available from each line in a plant breeding program necessitate the utilization of a nonreplicated yield-testing system. The modified, augumented design, which adjusts for environmental heterogeneity, is a nonreplicated testing system that has been adapted to make it suitable for yield-testing cereals. A careful and complete assessment of new experimental designs is essential to ensure that the advantages and disadvantages of the design are understood. This research reports the advantages in flexibility of field operations and illustrates the statistical requirements and the type of results that can be obtained from field data. The results illustrate the importance of having an accurate testing system, because the best lines chosen, based upon the most appropriate adjustment method suggested by the modified augumented design or unadjusted data, can vary by more than 50% in any given test.

Wheat

Fungicidal control of stripe rust. A 3-year field study showed that a single application of the systemic fungicides propiconazole, triadimefon, or fenpropimorph, before the heads of Fielder soft white spring wheat had completely emerged, provided effective control of stripe rust. Depending on disease severity, the use of these systemic fungicides resulted in yield increases ranging from 16 to 79%. This increase in yield resulted only partially from higher kernel weight. It appears that number of kernels per head was also increased through fungicidal control of stripe rust.

Cytogenetics of black point resistance. Tests of several hard red spring wheat cultivars against a causal agent of kernel black point showed that disease incidence was lowest in Cadet, intermediate to high in Apex, and highest in S-615 and Rescue. Inoculation of disomic substitution lines for chromosome 5B demonstrated that black point incidence in Cadet and Rescue was controlled by a gene or genes located on chromosome 5B. The F_1 progeny from crosses between Cadet and Rescue had a black point incidence similar to that of Rescue, indicating that resistance is a recessive trait. The level of resistance in Apex did not consistently lower the incidence of black point from the levels in S-615 and Rescue.

Cottony snow mold. The effect of cottony snow mold and freezing resistance on winter wheat survival in central and northern Alberta was studied during the winter of 1986 and 1987 at Lacombe and Fort Vermilion, Alta. Results showed that infection occurred in the stems and crowns and that the incidence of the pathogen in these tissues was closely associated with percent mortality. Infection became prevalent in stems and crowns during November and December at Fort Vermilion, and during January and February at Lacombe. Freezing resistance in wheat plants reached a maximum level by mid November and remained constant until mid March; it was not correlated with the incidence or severity of cottony snow mold. Environmental conditions, particularly the presence of a deep snow cover producing relatively constant soil temperatures between -1 and -5°C, appeared most conducive for development of cottony snow mold.

Common bunt. The level of resistance of western Canadian spring wheats and triticales to common bunt was determined in field studies. Triticales and durum wheats were designated immune or highly resistant. The hard red spring wheats were generally resistant; however, recently registered cultivars Roblin and Laura were susceptible. The prairie spring wheats and the soft white wheats were

generally susceptible. The reaction of the cultivars to individual bunt races evaluated under controlled environment conditions revealed that specific genes for bunt resistance, Bt7 and Bt10, were present in the cultivars Canuck and BW-553, respectively. In the remainder of the hard red wheats, the resistance appeared to be race nonspecific in nature. The potential for large areas planted with susceptible cultivars may lead to the reemergence of common bunt as an important disease that can reduce yield and quality in spring wheats in western Canada.

Insecticide residue chemistry

Aerial application studies. To evaluate properly an aerially applied insecticide, one must first determine that enough spray was deposited to achieve efficacy. Until now, the amount of spray deposited has been determined by conducting complex residue analysis on crop or soil samples taken from treated areas. As a new approach, we have developed methodology to quantitate aerial deposits by chemical analysis of artificial targets. We use commercially available, water-sensitive papers (wsp) as the artificial targets. A visual assessment of the spray deposits is made first, then the wsp are extracted to quantitate the deposits. Our analysis method recovered 97% of the deposits on the wsp. The wsp were much easier to analyze than crop or soil samples. In the field, the wsp were placed on top of stakes above the crop canopy. They had 91% trapping efficiency for the spray deposits and the trapped deposits were representative of the actual deposits on the adjacent crop and soil surfaces. We recommend the use of wsp in all experiments on aerially applied pesticides.

LIVESTOCK SCIENCES

Pest studies

Early detection of cattle grub infestations using ELISA. An enzyme-linked immunosorbent assay (ELISA) has been developed to detect animals infested with cattle grub during the fall in Alberta. The antibody to *Hypoderma lineatum* is detected as early as 6 weeks postinfestation in artificially infested steers. The peak in antibody concentrations preceded the peak in maximum apparent grub numbers, which occurred between 37 and 43 weeks after infestation. Natural infestations with *H. lineatum* and *H. bovis*, ranging from 1 to 92 grubs per calf, were readily detected by November, and the incidence of false positives in uninfested calves was only 5%. Low-level (one to four grubs) infestations of *H. bovis* only became detectable in February, and the antibody concentrations peaked at the end of April. Prevalence of cattle grub infestations in southern Alberta was shown to be 37% during this study. The cattle grub is a major pest affecting livestock in this province.

Scanning electron microscopy of the posterior spiracle of cattle grubs. Studies showed that posterior spiracles of newly hatched, first-instar larvae of *Hypoderma bovis* and *H. lineatum* consist of two pairs of spiracular openings. Each pair is surrounded by a rima bearing three spines. Posterior spiracles of second-instar larvae are composed of a pair of medial ecdysial scars bound laterally by spiracular plates. *H. bovis* spiracular plates have 29–40 openings, each surrounded by a slightly raised rima. *H. lineatum* spiracular plates have 18–25 openings. Spiracular openings of *H. bovis* lead to posterior felt chambers, which are connected to a common, anterior felt chamber filled with a mesh-like network. In third-instar *H. bovis* each medial ecdysial scar is surrounded by a strongly concave spiracular plate. Spiracular openings are surrounded by a slightly raised rima. Most rimae bear a spine. Spiracular plates of *H. lineatum* are flat, and rimae are without spines. Each spiracular opening leads to a posterior felt chamber, several of which are confluent with a larger anterior felt chamber. Anterior felt chambers open into the dorsal longitudinal tracheal trunk. Felt chambers in third-instar larvae are also filled with a complex mesh. This research increases our understanding of cattle grub adaptations to parasitism and aids in the identification of the two species.

Determination of residues on cattle hair. A simple method was developed for determining permethrin residues on cattle hair by gas–liquid chromatography with electron capture detection. This method is cost-effective, fast, and accurate and can be mechanized and automated. On a 10-mg sample of permethrin-treated hair, the average recovery of *cis*- and *trans* isomers was 95 and 100.7%, respectively. Using this method it was found that a dual-cloud electrostatic sprayer provided uniform body coverage with permethrin.

A simple method for the determination of fenvalerate residues on cattle hair by gas–liquid chromatography was developed and applied to determine the fenvalerate residues on cattle hair from Bovaid ear tags. Recovery rates were found to be 96–104% at 0.1–1.0 µg levels of fenvalerate. Fenvalerate was adequately distributed over the entire body and persisted for at least 80 days on the hair of cattle when applied with one Bovaid ear tag.

SOIL SCIENCE

Nitrogen fixation

Effect of rhizosphere bacteria on wheat growth. The effects of the associative N_2-fixing bacteria, *Azospirillum brasilense* and *Bacillus* C-11-25, on wheat growth were evaluated using conditions of very low (3 µg/g) and very high (1285 µg/g) levels of available N. Seedlings were inoculated with one of the bacteria or were left uninoculated as a control. At maturity, inoculated plants weighed less than uninoculated plants in the low-N mixture; however, both inoculated and uninoculated plants contained similar amounts of N. There was no indication of associative N_2 fixation that could be attributed to activities of the added bacteria in inoculated plants. Inoculated wheat in the high-N mixture produced more plant dry matter than uninoculated wheat. The average tiller height of inoculated plants was greater for inoculated wheat than for uninoculated plants. Endogenous gibberellin-like substances (GA1 and GA3) were identified in culture filtrates of the bacteria using high-performance liquid chromatography and a dwarf rice bioassay. It was concluded that the main effect of *A. brasilense* and *Bacillus* C-11-25 on wheat growth in these experiments was through alteration of plant growth and that the contribution of associative N_2 fixation by these bacteria to wheat N nutrition is minimal.

Plasmid-encoded genes. Derivatives of the transposon Tn*5*, carrying the Mob site (*oriT*) of plasmid RP4, and an *nptI-sacB-sacR* cassette were constructed. The Mob site allows identification of transposon inserts in cryptic plasmids by mobilization to other strains. The sac genes allow direct selection for the loss or curing of plasmids, because only strains that no longer contain an active *sacB* gene are able to grow on media containing sucrose. These transposons were tested in four strains of *Rhizobium leguminosarum* and two strains of *Rhizobium meliloti*, and curing of many large cryptic plasmids was achieved. Use of this method has enabled the identification of plasmids carrying genes involved in nodulation, nitrogen fixation, and various metabolic pathways, including genes involved in catabolism of various plant metabolites. These genes could be used in the construction of improved, genetically engineered *Rhizobium* strains. The transposons constructed should function for curing of plasmids in any Gram-negative bacterium.

Soil management and conservation

Nitrogen exudation through roots. Long-term crop rotation studies have demonstrated that continuous wheat production is very effective in sustaining nitrogen fertility in soil. A hypothetical mechanism for this beneficial effect is release of nitrogen from wheat roots into the soil via exudation and related processes. Quantification of plant nitrogen fluxes into the soil, however, has been impaired by the absence of appropriate methodology. A proposed method for the direct measurement of root nitrogen exudation was devised and evaluated under controlled conditions. Wheat plants, when exposed to atmospheric ammonia nitrogen, were found to absorb this nitrogen rapidly into the leaves and, furthermore, to translocate the assimilated nitrogen into the roots. Use of ^{15}N-labeled ammonia therefore permitted direct quantification of nitrogen released from the roots by analysis of the soil for ^{15}N. Preliminary estimates indicated that a substantial proportion (perhaps 20% or more) of the nitrogen assimilated by wheat was released into the soil by exudation and related processes. Use of this method will permit quantification of rhizosphere nitrogen dynamics under field conditions and will perhaps facilitate identification of crop plants or agronomic practices that ensure sustained soil productivity.

Soil rhizosphere. As plant roots grow through soil, they introduce changes to the surrounding soil. To examine the effect of roots on the chemical and biochemical properties of the rhizosphere, two grass species, blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) and rye (*Secale cereale* L. 'Frontier'), were grown on five different soils in simple containers consisting of five sandwiched compartments, simulating

rhizosphere and surrounding soil, over 5 weeks. Although the presence of roots influenced the measured chemical properties of the soil surrounding them, there were no overall common trends. For example, changes in pH over time were slight but consistent; they decreased in one and increased in the other four soils. The results, even in this simplified system, demonstrated complex and interrelated effects ($P < 0.01$) of soil type, plant species, and time on the biochemical dynamics in and near the rhizosphere. The properties of the rhizosphere are, therefore, system specific.

Restoring productivity to artificially eroded soil. A field was artificially eroded by leveling in 1957. Continuous cropping to barley for 7 years followed by a wheat–fallow rotation for 14 years without application of nutrients did not significantly improve the soil productivity of the severely eroded land. Subsequently, a wheat–fallow experiment was conducted from 1980 to 1985 to determine the effects of either 30 Mg/ha of feedlot manure or 150 kg commercial fertilizer N (as urea) and 150 kg commercial fertilizer P (as triple superphosphate) per hectare on restoring the productivity to soil from which either 10–20 cm or ≥46 cm of soil had been removed. Both the manure and commercial fertilizer treatments essentially restored productivity within the 1st year, as measured by wheat yields, regardless of severity of erosion. During years of drought stress, which often occur under dryland conditions, the manure application on the eroded soil treatments resulted in yields greater than those on check or fertilized plots. The manure significantly increased the organic matter, total N, NO_3-N, available P, and water-stable aggregate status of the soil. The difference in carbohydrates between undisturbed and eroded plots decreased from 1982 to 1984.

Water and climate

Automation of weather systems. An automated system of data collection and data management for climatic data is invaluable at research institutions of applied sciences such as agriculture and forestry. A climatic data management system implemented at the Lethbridge Research Station uses off-the-shelf dataloggers and sensors for data collection. Sufficient flexibility is built into the data collection system to accommodate standard climatic measurements as well as nonstandard measurements in support of local research activities. The data collected are processed in a data management program to provide quality control, to update historical archives, and to produce reports for investigators both at the station and at external agencies such as Environment Canada. The integration of historical archives with the most current climatic data collected provides a resource to researchers wherein most of the required climatic information is readily available.

Canal linings for seepage control. Seepage from canals is the major cause of waterlogged and saline land in the irrigation districts of southern Alberta. Studies at the station have been directed toward finding a suitable lining to control canal seepage under the semiarid continental climate of the area. Black polyethylene plastic covered with patio blocks (concrete slabs either 610 or 760 × 610 × 30 mm thick) was the only one of four linings tested to control seepage satisfactorily and was essentially maintenance-free throughout the 5-year study. Because of its flexibility, it was not damaged by frost heaving and was easily fitted to the ditch. The ditch surface had to be smoothly trimmed to size and shape to make a good bed for the blocks. Maximum deterioration in the yield and breaking strengths of the plastic was <5%. This concept of canal lining has been used by one irrigation district, and another district is considering its use.

Instrumentation for monitoring water levels. The increasing demand for reliable and detailed data on use of water in irrigation has encouraged the use of digital systems for data acquisition. An instrumentation system for simultaneous recording of water-table heights in digital and graphical forms was developed. The major components of this device were a float-potentiometer (float-pot) unit, an electronic datalogger, and a Stevens F1 recorder. The instrumentation system has worked very well for monitoring water levels at a stream flow station in an irrigation canal, where water level changes rapidly. The float-pot unit transferred absolute water level positions electronically to an electronic datalogger in any preset, incremental time interval, while mechanically operating the clock-driven pen carriage and chart drum recorder. Data stored in the datalogger were transferred to floppy disk through an RS-232 communication interface and a portable IBM-compatible microcomputer. The raw data were processed,

transformed into water levels, and compared with those simultaneously obtained by the chart. The results indicated that the data obtained by the electronic datalogger were highly accurate. The proposed system has provided an excellent concurrent digital and graphical record of water levels with a high level of accuracy.

Glauber's salt in a Dark Brown soil. An unknown efflorescent mineral, occurring at a depth of about 1 m in a moderately well drained soil of southern Alberta, was identified by chemical analysis as Glauber's salt, the hydrated sodium sulfate mineral mirabilite. X-ray diffraction analysis of dehydrated crystals identified the anhydrous sodium sulfate mineral thenardite. The mirabilite crystals occurred in unsaturated soil beneath a melting frozen layer. Saturation extracts of bulk soil samples identified two zones of high ionic concentration, at the depth of mirabilite occurrence and below the water table. The dominant ions in these zones were sulfate and sodium and, to a lesser extent, magnesium. All saturation extracts and soil solutions from below the frozen layer and the groundwater were found to be saturated with respect to calcite, dolomite, and gypsum. Only the soil solutions from the 90–120 cm depth showed saturation with mirabilite. Mirabilite formation was attributed to the low soil temperatures, high soil water contents, and concentration of ions below the frozen layer.

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Research

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Research Station
Agassiz, British Columbia

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INTRODUCTION

The Agassiz Research Station celebrated its 100th anniversary in 1988 with the burial of a time capsule that will be opened in the year 2088. The station was one of the original five established in Canada.

The station is situated in the lower Fraser Valley of British Columbia where the majority of the province's dairy, poultry, vegetable, and berry industries are located. The mandate of the station is to conduct research in both plant and animal sciences.

Dairy research is directed towards the nutrition of cattle, including mineral biochemistry of ruminants. The program is supported by the forage specialist and by the facilities in the station's feedmill. The poultry program, which is operated with the tangible support of the British Columbia poultry industry, emphasizes nutrition, physiology, and animal behavior. These programs have been recognized nationally and internationally.

The station's research on horticultural crops has a broad mandate, which includes management, physiology, postharvest physiology, entomology, and plant pathology of greenhouse and field vegetable crops and management of berries, including kiwi fruit. Weed control studies address both chemical and nonchemical methods of control. The programs are supported by research in soils on a wide range of management and fertility problems.

The station's programs are directed towards sustainable systems of soil, plant, and animal management with a view to maintaining and improving the rural environment.

Further information regarding the research programs and results achieved may be obtained by requesting copies of the listed publications and other informal reports. Address requests to the Director, Research Station, Research Branch, Agriculture Canada, P.O. Box 1000, Agassiz, B.C. V0M 1A0; Tel. (604) 796-2221.

J.M. Molnar
Director

ANIMAL SCIENCE

Apparent tissue mineral changes related to sudden death syndrome in chickens. Sudden death syndrome (SDS) is the main cause of mortality in male broiler chickens in western Canada, although the etiology of the disease is essentially unknown. The objective of recent work was to screen tissues from SDS birds and to identify mineral elements that might be present in concentrations higher or lower than in healthy chickens. Sixty-eight elements in heart, liver, lung, and kidney were determined semiquantitatively by inductively coupled plasma mass spectrometry. Apparent concentrations of bromine, calcium, iron, germanium, and strontium were higher in one or more tissues from SDS chickens, whereas apparent concentrations of cesium, magnesium, manganese, phosphorus, rubidium, and zinc were lower compared with the healthy controls. Thus, a number of mineral elements may be related to SDS in some manner.

Use of pen space by broiler chickens. An investigation was made of the use of pen space by broiler chickens kept in two different sizes of pens, large (407 m^2 for 3040 birds) or small (203.5 m^2 for 1520 birds). The area of the daily home range of individual chickens within each flock was relatively small and was unaffected by the pen size. However, the location of individuals within pens generally changed over time such that the total area of space used during the period from 4 to 9 weeks of age was relatively large and was greater for chickens in the large pens than for those in the small pens. The results indicated that chickens were not restricting their movements to a small area of their pen where they could develop and maintain social relationships with other chickens in the vicinity. Lack of a well-delineated home site, and constant mingling with strangers, may have an adverse effect on the welfare of broiler chickens.

Effect of dietary boron on eggshell quality. Postmenopausal human females were reported to deposit more bone calcium when their diet was supplemented with boron. Feeding supplemental boron to laying hens that had been molted and then brought back into egg

production did not influence eggshell quality as measured by the specific gravity method or by measuring eggshell thickness.

Formaldehyde as a preservative. Residual formaldehyde (CH_2O) in the tissues, blood, and milk of calves and cows fed whey preserved with various levels of formalin was measured by gas chromatography. The morning milk from cows fed whey preserved with 0.05, 0.10, and 0.15% formalin contained CH_2O at an average of 0.034, 0.095, and 0.208 mg/kg, respectively. Fresh muscle tissue from calves consuming whey preserved with 0.10% formalin had a significantly higher concentration of CH_2O (0.256 mg/kg) than fresh muscle tissue from control calves or calves consuming whey containing 0.05% formalin (0.178 and 0.206 mg/kg, respectively)

Dogfish silage. In a cooperative study with B.C. Research and the Department of Animal Science, University of British Columbia, wastes (*Squalus acanthias*) from processing dogfish were readily hydrolized in the presence of 1.5% formic acid to produce a stable, liquid product free of bones and scales. The rate and extent of solubilization was temperature-dependent. The resultant acidified product contained 74.4% moisture, 3.0% nitrogen, and 3.4% ash and was stable for 6 months at ambient temperatures. However, when fed as a single feedstuff to rats, the biological value of the silage was low and was not improved by the addition of lysine or methionine.

PLANT SCIENCE

Computer-assisted watershed hydrology studies. The suitability of the digital elevation model (DEM) and of electronic land image manipulation for watershed quantification was studied in a small British Columbia watershed with terrain varying from flat lowland to about 75% slope upland. Results suggest that DEM allows the creation of synthetic watershed images with contour overlays for accurate and economical landscape descriptions. Through the use of proper software, DEM also provides more accurate measurement of watershed areas and profiles than traditional planimetric procedures. With the increased availability of digitized topographic data and improved resolution of aerial photo and satellite landscape images, DEM will be a useful tool in the field of agricultural hydrology.

Cucumber yellowing—a challenge for the greenhouse industry in British Columbia. The marketability of greenhouse cucumbers is dependent on several factors, one of which is yellowing. Shelf life is reduced by yellowing. In a survey of six commercial growers, cucumbers were collected weekly for 11 weeks. Shelf life of these cucumbers varied greatly and ranged from 2 to 14 days. Average shelf life ranged from 5.1 to 9.0 days among growers and from 5.0 to 7.5 days depending on week of harvest. Smaller fruit (440 g) lasted longer than larger fruit (580 g). Analysis of mineral content of fruit showed that shelf life was negatively correlated with nitrogen, boron, and calcium and positively correlated with magnesium and zinc. Fruit that was kept longer on the plants had a shorter shelf life than fruit that was harvested at an earlier age.

Effect of fertilizers on weed emergence and weed communities. Results of trials conducted from 1986 to 1988 on the effect of fertilizer on weed emergence and subsequent weed communities indicate that application of nitrogen stimulates emergence of corn spurry seedlings. After a few weeks, lady's-thumb or lamb's-quarters assumed biomass dominance in the presence of nitrogen, whereas corn spurry was dominant on plots with no nitrogen. Phosphorus had a small effect and potassium had no effect on composition of weed communities. The ability to manipulate weed emergence and communities may have implications in choice of strategy and ease of weed control.

Response of cantaloupe to row covers and honey bees. Two cantaloupe cultivars were grown on black plastic mulch (BPM) alone or on BPM plus floating mulch (Agryl P-17). The two floating mulch treatments either had, or did not have, honey bee colonies placed under them. Introduction of pollinating insects allowed for a 4-week extension of the covering period; row covers without bees had to be removed as soon as blossoms appeared. Early yield was 23 times greater from the covered than from the uncovered treatments. Floating mulch with bees resulted in the greatest early and total yields.

Supplemental lighting of greenhouse vegetables. A comprehensive review of available information on the use of supplemental lighting was published. Current use of supplemental lighting of greenhouse vegetables is largely restricted to propagation and transplant production. Yield data from trials with

lettuce, cucumber, tomato, and pepper, grown under supplemental lighting during each crop's main growth period, are promising, but more information is needed, particularly on product quality. Supplemental lighting increases the effectiveness of enriching carbon dioxide in the greenhouse but may necessitate adjusting nutrients and climate in the greenhouse.

Host range of Fusarium oxysporum f.sp. radicis-lycopersici. The roots of young seedlings of different plant species were inoculated with four different isolates of *Fusarium oxysporum* f.sp. *radicis-lycopersici* to evaluate their susceptibility to this pathogen. Susceptible plant species included asparagus, barley, broad beans, pinto beans, snap beans, beets, Brussels sprouts, cucumber, onions, peas, spinach, horned melon, chard, kohlrabi, tomatoes, chickweed, sweetclover, red clover, curled dock, wild buckwheat, corn spurry, hairy galinsoga, and narrow-leaved plantain. Species not observed to be susceptible included broccoli, corn, dill, eggplant, fennel, kiwifruit, leeks, pepper, potato, zucchini, canola, French marigold, rutabaga, common groundsel, barnyard grass, perennial rye grass, white clover, and lamb's-quarters. Susceptible plant species may be important as reservoirs of inoculum of the pathogen.

Biological control of fusarium yellows of celery. The use of *Bacillus subtilis*, *Talaromyces flavus*, and *Trichoderma* sp. and a cocktail of three avirulent *Fusarium* species were assessed as root inoculants to control fusarium yellows of celery on celery cultivars 52-70HK and 52-70R. The biological control agents did not significantly affect disease severity, celery fresh weight, or marketability for either cultivar. However, celery 52-70HK was observed to be less susceptible to fusarium yellows than 52-70R. Significantly lower ratings for disease severity and greater fresh weights were observed for cultivar 52-70HK than for 52-70R.

Biological control of Botrytis cinerea on kiwifruit. Four fungi, *Drechslera* sp., *Fusarium heterosporium*, *Myrothecium verrucaria*, and *Trichoderma viride*, were compared with the fungicide Rovral (a.i. iprodione) for controlling the infection of the stigmata of kiwifruit. Only Rovral significantly reduced the percent infection of the stigmata, but Rovral did not reduce infection significantly better than *Drechslera* sp., *F. heterosporium*, or *T. viride*.

Kiwifruit cold tolerance. The successful cultivation of kiwifruit in British Columbia requires an understanding of conditions and temperatures that will damage the plants. Kiwifruit plants and tissue pieces were exposed to a ramp and soak program during the fall, winter, and spring using controlled environment chambers developed for this study. The electrolyte leakage, determined on the phloem tissue and 1-year-old buds from both the scion and the rootstock, was a good indicator of frost damage and was closely related to bud death, ringbarking, discolored exudate, and reduced growth. In general, the percentage of electrolyte leakage was much greater when tissue was damaged and this increase was higher for the 1-year-old buds than for the phloem tissue from the trunk. The tissues most susceptible to cold temperatures were the undifferentiated and differentiating floral buds in winter and spring. Floral bud differentiation was influenced by cold temperatures in November, December, and January (−8 to −10°C) but warmer temperatures (0 to −0.5°C) caused damage to flower buds during development, which resulted in flower abortion or the development of misshapen fruit.

Kiwifruit frost protection using insulation wraps. Damage to trunks by cold temperatures usually occurs between 15 and 60 cm above ground level. A good trunk wrap is one having good properties for thermal insulation that reduces heat loss and trunk heating and minimizes diurnal temperature fluctuations. Ideal wraps will provide long lags in temperature increases and decreases. The wraps that moderate daily maximums also influence plant cold tolerance by changing the acclimation and reducing the freezing–thawing stress. At all test times the minimum air temperature was cooler than the minimum temperature under all wraps tested. Sawdust, followed by foam, foil, and white paint, provided the greatest increase in minimum temperatures. The wraps (with one exception) and the white painted trunks reduced daily maximum temperatures over the control. White polyethylene foam increased daily maximum temperatures over the control. White polyethylene foam and sawdust were most effective in reducing the amount of damage under the wrap. In some cases the damage above the wrap was increased. Painting the trunk with white paint above the wrap reduced trunk damage above the wrap.

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Research Station
Kamloops, British Columbia

PROFESSIONAL STAFF

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K.J. Robinson	Administrative Officer
W. Majak, B.Sc., M.Sc., Ph.D.	Biochemistry
P.S. Mir, B.Sc., M.Sc., Ph.D.	Ruminant nutrition–physiology
Z. Mir,[1] B.Sc., M.Sc., Ph.D.	Ruminant nutrition–physiology
D.A. Quinton, B.S., Ph.D.	Range management
R.B. Reaney	Computer systems
D.G. Stout, B.S.A., M.Sc., Ph.D.	Plant physiology
A.L. van Ryswyk, B.S.A., M.S.A., Ph.D.	Soil science

Prince George Experimental Farm

K. Broersma, B.S.A., M.Sc.	Superintendent; Forage agronomy

VISITING SCIENTIST

D.J. Thompson, B.Sc., M.Sc., Ph.D. National Research Council visiting fellow	Grass–legume establishment

[1] Transferred from Melfort Research Station, 1 April 1988.

INTRODUCTION

The research programs at the Kamloops Range Research Station and the Prince George Experimental Farm are designed to serve the ranchers and managers of the diverse rangelands and farmlands in southern and central interior British Columbia. Research is focused on developing and transferring new technology in the fields of range management, plant ecology, poisonous plants, bloat, winterhardiness, forage agronomy, quality of conserved forages, and animal nutrition.

Our professional staff acquired one additional scientist with the transfer of Dr. Zahir Mir from the Melfort Research Station. He is conducting research in the areas of ruminant nutrition and digestive physiology through investigations into improvement of digestibility and intake of fibrous feeds for ruminants and determination of compositional changes in forages during harvest and storage.

Further information on our research activities is available from the Director, Research Station, Research Branch, Agriculture Canada, 3015 Ord Road, Kamloops, B.C. V2B 8A9, Tel. (604) 376-5565; or the Experimental Farm, R.R. 8, RMD #6, Prince George, B.C. V2N 4M6, Tel. (604) 963-9632.

J.A. Robertson
Director

RESEARCH ACTIVITIES

Evaluation of alfalfa winter injury

Each spring, growers of alfalfa (*Medicago sativa* L.) must normally wait for several weeks of warm weather before knowing whether their alfalfa survived the winter. The 1985–1986 winter at Kamloops had low temperatures during a period with no snow cover. Early in the spring, before growth began, alfalfa plants were dug from the field and various root and crown lesions were identified and rated according to severity. Numerical ratings of one to three or four were used, with the lowest number indicating dead plants and the highest number indicating no visual indication of injury. The plants were then put into pots of soil and grown for 6 weeks to determine if they would live or die. The relationship between lesions present at the time of digging and survival was then studied to see if the lesions could be used to predict survival. Injuries to several characteristics were found to be associated with plant death: bud vigor, leaf vigor, resistance of root bark to peeling, resistance of root to squeezing, root interior color, and, depending on site, the presence of fungi on the root surface. A model combining injury ratings for three characteristics (bud vigor, root color, and root resistance to peeling) was developed, and survival probabilities based on this model were determined. Use of this model will allow for an early evaluation of low-temperature injury without having to wait for aerial growth to occur.

Nitrogen-fertilized crested wheatgrass

Crested wheatgrass (*Agropyron cristatum* L.) at three sites on Chernozemic soils was fertilized once in the fall with nitrogen at 0, 25, 50, and 100 kg/ha and harvested for 7 years. Yields of crested wheatgrass were greatest on the two moister sites (Dark Brown Chernozems) in the 2nd and 3rd (wettest) years of harvest for the highest fertilization rate. These yields ranged up to double that of the control yield (1.0 t/ha). Low yield and yield response on the driest site (Brown Chernozem) was likely the result of a history of drought and phosphorus deficiency.

It is important to increase the yield of an early growing forage, such as crested wheatgrass, so that shortages of winter feed can be alleviated. However, when the greatest yield response does not occur in the 1st year, because of yearly variation of moisture supply, the return on investment will be delayed and therefore less valuable.

Yield and quality of grass–legume mixtures

Response of forage crop mixtures, including combinations of timothy (*Phleum pratense* L.), reed canarygrass (*Phalaris arundinacea* L.),

orchardgrass (*Dactylis glomerata* L.), red clover (*Trifolium pratense* L.), white clover (*T. repens* L.), alsike clover (*T. hybridum* L.), birdsfoot trefoil (*Lotus corniculatus* L.), and alfalfa (*Medicago* spp.), to increasing rates and split applications of nitrogen was determined at three locations in the central interior of B.C. An additional part of the study determined crop response to nitrogen, phosphorus, potassium, and a mixture of micronutrients that included copper, zinc, boron, and molybdenum. The field trials were conducted on Pineview clay at Prince George, Doughty clay at Smithers, and Driftwood loam at Smithers.

Use of nitrogen fertilizer increased yields of forage dry matter by 100–200% compared with plot areas receiving no nitrogen fertilizer. Nitrogen fertilizer did not increase the quality of the forage, as both the crude protein and percent digestibility decreased with increasing amounts of nitrogen at moderate rates. Split applications of nitrogen increased yields between 2 and 5% over single applications in spring. These minor increases do not warrant two separate applications. The minus trial showed that nitrogen was the most limiting nutrient. Phosphorus was also limiting but to a lesser extent. Potassium and the micronutrients tested were not deficient. Nitrogen was the most economical fertilizer element to apply in that the returns from the applied fertilizer more than paid for the extra input costs.

Pasture bloat in cattle

Rumen-fistulated cattle were fed fresh alfalfa herbage daily during two growing seasons. Samples of rumen fluid were collected daily prior to feeding and the frothiness of the rumen fluid was assessed. Concentrations of soluble protein nitrogen in the rumen fluid were higher in animals that subsequently bloated than in those that did not ($P < 0.01$). There was no relation between soluble protein nitrogen and the occurrence of foam in the rumen prior to feeding. The concentrations of sodium and potassium in the rumen fluid were negatively correlated. Bloat was associated with a low concentration of sodium and a high concentration of potassium ($P < 0.01$). Concentrations of calcium and magnesium were lower than those of the two monovalent ions but were positively associated with bloat ($P < 0.01$). The high concentration of chlorophyll associated with a predisposition to bloat may be the result of a colloidal aggregation of chloroplast particles stabilized by cations.

Cyanide potential of saskatoon

The saskatoon shrub (*Amelanchier alnifolia* Nutt.) is widely distributed in temperate regions of North America. It has a diverse range of habitats, extending from near sea level to subalpine. The shrub is browsed by both domestic and wild ruminants but large intakes can be fatal, owing to the natural occurrence of a cyanide-containing compound, prunasin. Prunasin is broken down rapidly in the rumen with the resultant release of hydrogen cyanide, which can be lethal at 2 mg/kg of body weight. The most hazardous period for ruminants appears to be in spring during the bloom stage, when saskatoon plants contain high levels of prunasin in both leaves and twigs.

The lethal potential of this shrub was first demonstrated at the Kamloops Research Station when deer were inadvertently killed by being fed a pure diet of saskatoon twigs. However, in subsequent studies with rumen-fistulated cattle given saskatoon, the expected levels of cyanide in rumen fluid were not generated and only trace quantities of cyanide could be detected. This prompted us to reexamine the local variation in prunasin levels of saskatoon foliage.

A survey was done in the immediate Kamloops area, within 16 km of the station, along the North Thompson and Thompson rivers, from the grasslands on the valley floor into the forest in the adjoining hills. Saskatoon samples were collected in the early bloom stage from 25 sites for prunasin analysis. Later, in the full-bloom stage, another sample was taken from each shrub, for identification of the plant. It was determined that there are two varieties of saskatoon in the Kamloops area, and that their genetic difference is responsible for a difference in toxicity. These two varieties are only readily distinguishable during the bloom stage because flower characteristics are used for identification.

Grazing control of Columbia milk-vetch

The growth and miserotoxin content of Columbia milk-vetch (*Astragalus miser* var. *serotinus* Dougl. ex Hook) were examined following grazing of early growth by cows at a grassland site in southern British Columbia during 1987. Growth of Columbia milk-vetch was determined by measuring the freeze-dried weight of each plant and miserotoxin levels were determined by a rapid screening method.

Cows either avoided Columbia milk-vetch or consumed it incidentally with other forage so long as there was adequate grass available. As grass became scarce the use of Columbia milk-vetch increased. After being grazed, the rate of growth and the toxicity of Columbia milk-vetch were substantially reduced. In comparison to ungrazed plants, the above-ground biomass of grazed plants was reduced by >50% and the average miserotoxin content per plant was reduced by >75% during a 6-week period of regrowth.

Although early grazing may reduce the potential hazard of Columbia milk-vetch to livestock, the plant is not a preferred food and may not be eaten by cattle until other forage becomes scarce. Heavy grazing intensity may, in turn, result in low vigor of bunchgrasses and a deterioration of range conditions which, in turn, may result in more weeds in the plant community. Clearly these aspects of management require further study.

Estimation of extent of feed degradability in the rumen

Degradabilities were determined for alfalfa, orchardgrass hay, alfalfa silage, corn silage, cracked corn, and orchardgrass at 70:30 ratio, and barley straw and alfalfa at 70:30 ratio. Samples were incubated in nylon bags for a period equal to the rumen retention time (estimated as reciprocal of the particulate rate of passage of each feed) of these forages. Degradabilities at rumen retention time were found to be correlated ($r > 0.8$, $P < 0.05$) with the effective degradabilities of the feeds, which were estimated from the readily soluble fraction, the potentially digestible fraction, the rate of degradation, and the rate of passage of the feeds from the rumen. However, the hourly rates of passage of the feeds ranged from 2.8 to 3.3% and could be estimated ($r = 0.57$, $P < 0.0004$) from total dry matter consumed along with dry matter intake expressed as percent of body weight and content of acid detergent fibre and lignin. These results indicate that estimates of effective degradabilities can be obtained by incubating feed samples (in nylon bags) for a period equal to the rumen retention time, which is the reciprocal of the rate of passage—a technique that will significantly reduce the time and labor required for determining effective degradabilities of feedstuffs.

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Research Station
Summerland, British Columbia

PROFESSIONAL STAFF

D.B. Cumming,[1] B.S.A., M.Sc., Ph.D.	Acting Director
R.D. McMullen,[2] B.Sc., M.S., Ph.D.	Associate Director
L.C. Godfrey, B.Sc.	Head, Administration
P. Watson, B.A., M.Lib.	Librarian
J. Wild, B.Sc., M.Div.	Computer Systems Manager

Entomology–Plant Pathology

R.S. Utkhede, B.Sc.(Agr.), M.Sc.(Agr.), Ph.D.	Head of Section; Tree fruit fungus diseases
F.L. Banham, B.S.A.	Stone fruit insects
J.E. Cossentine, B.Sc., M.S., Ph.D.	Integrated control
V.A. Dyck, B.A., M.Sc., Ph.D.	Management of codling moth
K. Eastwell,[3] B.Sc., Ph.D.	Biotechnology
A.J. Hansen, Dip.Agr., M.Sc., Ph.D.	Tree fruit virus diseases
R.D. McMullen, B.Sc., M.S., Ph.D.	Pear pest management
P.L. Sholberg, B.Sc., M.Sc., Ph.D.	Tree fruit fungus diseases

Food Processing

H.J.T. Beveridge, B.S.A., M.Sc., Ph.D.	Head of Section; Food chemistry and analytical methods
M. Cliff, B.Sc.(Agr.), M.S.	Food quality
D.B. Cumming, B.S.A., M.Sc., Ph.D.	Food technology
G.E. Strachan, B.S.A., M.Sc.	Enology and food technology

Pomology and Viticulture

N.E. Looney, B.S., M.S., Ph.D.	Head of Section; Pomology–plant physiology–growth regulators
E.J. Hogue, B.S.A., M.S., Ph.D.	Herbicides–vegetation management–nutrition
F. Kappel,[4] B.Sc., M.Sc., Ph.D.	Tree fruits management research
W.D. Lane,[5] B.Sc.(Agr.), M.Sc., Ph.D.	Apple–cherry breeding
M. Meheriuk, B.Sc., B.Ed., M.Sc., Ph.D.	Fruit storage and biochemistry
H.A. Quamme, B.S.A., M.Sc., Ph.D.	Orchard management–hardiness
A.G. Reynolds, B.Sc.(Agr.), M.Sc., Ph.D.	Grape management

Soil Science and Agricultural Engineering

D.S. Stevenson, B.S.A., M.S., Ph.D.	Head of Section; Soil moisture
A.P. Gaunce, B.Sc., M.Sc., Ph.D.	Pesticide and environmental chemistry
P.B. Hoyt, B.Sc., M.S., Ph.D.	Soil chemistry and management
A.L. Moyls, B.A.Sc., M.S., Ph.D.	Agricultural equipment—development and assessment
G.H. Neilsen, B.Sc., M.Sc., Ph.D.	Soil fertility and plant nutrition
P. Parchomchuk, B.A.Sc., M.S., Ph.D.	Agricultural equipment—development and assessment

VISITING SCIENTISTS

O.L. Lau,[6] B.S., M.S., Ph.D.	Pomology and viticulture
W.A. Su,[7] M.Sc.	Pomology and viticulture
J.D. Holley,[8] B.Sc., M.Sc., Ph.D.	Plant pathology
A. Levesque,[9] B.Sc., M.P.M.	Plant pathology

Graduate students

M. Gardiner, B.Sc.	Entomology
R. Smith, B.Sc., M.Sc.	Entomology

Departures

N.P.D. Angerilli, B.Sc., Ph.D. Resigned 27 July 1988	Orchard mite control, San Jose scale
D.M. Bowden, B.S.A., M.S.A., Ph.D. Resigned 1 September 1988	Director

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[1] Appointed Acting Director, 1 September 1988.
[2] Appointed Associate Director, 1 September 1988.
[3] Appointed 1 June 1988.
[4] Transferred to Summerland from Harrow Research Station, 8 February 1988.
[5] On transfer of work to the Fruit Tree Research Station, Tsukuba, Japan, under a Japanese Science and Technology Agency Fellowship, 15 December 1988–15 October 1989.
[6] Okanagan Federated Shippers Association, Research Associate.
[7] On transfer of work from Shanghai Institute of Plant Physiology, Academia, Sinica, from January 1988–December 1988.
[8] Agrifood Regional Development Subsidiary Agreement, Research Associate, September 1986–May 1988.
[9] Agri-food Regional Development Subsidiary Agreement, Research Associate, June 1988–October 1988.

INTRODUCTION

The Summerland Research Station, located in the Okanagan Valley of southern interior British Columbia, conducts research concerned primarily with solving problems of production and utilization of tree fruits and grapes with the objectives of increasing production efficiency, reducing production costs, and providing high-quality products to consumers. Studies are also carried out at substations located at Kelowna to the north and Creston to the east and in growers' orchards and vineyards in the Okanagan, Similkameen, and Creston valleys. Cooperative involvements in research with food-processing companies extend Canadawide.

1988 was a year for staff changes. Dr. Frank Kappel joined the staff, transferring from the Harrow Research Station to work in pomology on stone fruits. Dr. Ken Eastwell (formerly of Simon Fraser University) joined Agriculture Canada and the Entomology–Plant Pathology Section to research rapid methods of detection and identification of plant viruses. Ms. Margaret Cliff completed her M.Sc. at the University of California (Davis) and returned to work in the Food Processing Section. She was appointed to a biologist position and will research food quality. Dr. Nello Angerilli resigned his position in entomology to take an overseas assignment with the Eastern Indonesia Universities Development Project. A major staff change at Summerland saw Dr. Dave Bowden resign as director after a hectic tenure during which the new office–laboratory complex was completed, occupied, and brought on-stream as a productive research facility.

A significant event for the station was the unanimous approval by fruit growers of a regional sterile insect release program that is expected to eradicate the codling moth within 5–6 years. Research for this program was begun here some 30 years ago. The grape and wine industry of British Columbia was hit hard by recent GATT rulings and certain provisions of the Canada–United States trade agreement. Adjustment will require some years and research will be a cornerstone of developing the surviving components of the industry. The agri-food industry has been calling upon Summerland to participate in research ventures, and an unprecedented number of externally funded cooperative projects are under way. International involvement continues with visitors welcomed and our scientists traveling abroad. Dr. David Lane was selected to receive a Japan Science and Technology Agency Fellowship; he began his tenure at Tsukuba in December 1988.

This report contains brief statements of some major achievements attained at this establishment during 1988. Further information may be obtained from publications listed at the end of this report or from individual scientists. Requests for information or reprints should be addressed to the Director, Research Station, Research Branch, Agriculture Canada, Summerland, B.C. VOH 1Z0; Tel. (604)494-7711.

D.B. Cumming
Acting Director

SOIL SCIENCE–AGRICULTURAL ENGINEERING

Comparison of leaf and soil tests to diagnose Zn deficiency of apples

Soil Zn, extracted by 0.25 *M* $MgCl_2$ or DTPA as an index of plant-available Zn, was compared with Zn or P:Zn concentration in leaves for 40 commercial apple orchards in southern British Columbia. Sampled trees included a range of ages and cultivar–rootstock combinations. Leaves were sampled from the mid-portion of a current season's shoots four times; in May–June 1984, July 1984, May 1985, and July 1985. At these times the severity of the four deficiency symptoms (rosetting, blind bud, little leaf, and chlorosis) was assessed. Little relationship was found between soil and leaf Zn measures, except in July 1984, when both terminal leaf Zn and P:Zn concentrations varied directly with 0.25 *M* $MgCl_2$ extractable soil Zn. Soil Zn extracted by 0.25 *M* $MgCl_2$ was more closely related to severity of deficiency symptoms on the trees at all four sample dates than was DTPA-extracted soil Zn or leaf Zn concentration. Blindbud was the most useful indicator of deficiency in samples collected in May, whereas chlorosis was the most useful one in July.

Application of wastewater to tree fruits and grapes

Macspur McIntosh and Red Chief Delicious apples on M.7a rootstock were subjected to treatments involving all combinations of two types of irrigation water (well water or municipal wastewater from 1983, the year of planting) and three annual rates of N fertilization per tree (0, 200, 400 g NH_4NO_3), 1984–1987. The zero N treatment was increased to an annual rate per tree of 100 g NH_4NO_3 in 1986 because of low vigor of these trees. Wastewater irrigation increased the concentration of N, P, and K in the leaves in 4 of 5 years for McIntosh, whereas N, P, and K in leaves increased in 1, 4, and 2 years, respectively, for Delicious. Wastewater irrigation increased the increment in trunk diameter, 1983–1987, and fruit number and yield in 1985–1986 for both cultivars. No major horticultural limitations to the use of wastewater for irrigation were observed. N fertilization increased leaf N in 3 years for McIntosh and 2 years for Delicious, whereas leaf P and K were decreased at highest N rates in 2 years for each cultivar. N fertilization did not increase trunk diameter and increased fruit number and yield only in 1986 after 3 years of a zero N treatment. The results implied a role for P in the establishment and early growth and yield of young apple trees.

Okanagan Riesling vines were subjected to a similar experimental design, 1984–1987 and their response differed from apples. Wastewater-irrigated vines had increased P, K, and Ca in petioles but decreased Mg and, for 2 of 3 years, decreased N during August. Increased rate of N fertilization increased petiole N at time of bloom but not in August, had minor effects on petiole P, K, Ca, and Mg, and increased petiole Mn at highest N rates, especially (2 of 4 years) in association with wastewater irrigation. Yield increased both for vines irrigated with wastewater and linearly with rate of applied N in 2 of 3 fruiting years. Increased yield was not associated with increased petiole N concentration in August. Minor increases were measured for soluble solids and juice pH at harvest for wastewater-irrigated grapes in 2 years.

Identification of K deficiency in local orchard soils

Growth responses of apples to K fertilization have been identified both under laboratory conditions using apple seedlings and in a grower orchard with McIntosh on M.4 rootstock. This finding has not previously been reported for the irrigated tree fruit area of British Columbia and is apparently another factor that could be associated with the poor growth of young apple trees. In the orchard, K deficiency was associated with concentrations of leaf K below 1% and low values for extractable soil K, which averaged 39 µg/g throughout the surface 30 cm of soil. Applications of K fertilizer at planting time increased leaf K even though the fertilizer was applied near the surface. Although this site was found likely to respond to K fertilization, present indications are that such response will not be general as most orchards in southern British Columbia have adequate, even high, available K.

FOOD PROCESSING

Modified atmosphere packaging

Research was initiated on the characteristics of low-oxygen respiration of several commodities including cherries, apricots, peaches, plums, apples, tomatoes, and green peppers. As O_2 levels dropped, the products exhibited two or more consecutive, first-order reactions (O_2 consumption rate was proportional to the quantity of O_2 present) whereas CO_2 was produced at a constant rate, implying a zero-order reaction. The respiratory quotient was not constant but reflected these varying rates. At very low O_2 levels, the quotient rose sharply as O_2 consumption dropped off and most CO_2 was produced anaerobically.

The first-order O_2 reaction rates were matched with first-order O_2 diffusion rates through a small hole in a product container. This self-generated equilibrium enabled Lambert cherries to be stored at 0°C for >3 months in an atmosphere of 5–8% O_2 and 22–26% CO_2. The fruit retained its size, weight, and firmness and tasted quite acceptable despite dropping two percentage points in sugar content.

Experiments were also conducted to measure the oxygen diffusivities of flesh and skin of the McIntosh apples, which were found to be much lower (1/40th for skin and 1/20–1/110th for flesh) than theoretical estimates in the literature. These findings imply that cellular oxygen levels can indeed be reduced to no longer saturate all the

cytochrome oxidase when external atmosphere levels are still relatively high (15–20% O_2). Hence, the cytochrome oxidase–oxygen reaction appears to be the limiting factor in aerobic respiration.

Application of small-amplitude oscillatory testing to pectin gelation

The setting characteristics of pectin gels during cooling from 105 to 25°C and reheating to above 100°C have been determined using small-amplitude oscillatory testing. A versatile food rheometer designed and built by the Engineering and Statistical Research Centre of Agriculture Canada was used for the study. Gel strength during cooling was correlated linearly to temperature down to 30°C at least. On reheating, the gel softened initially then transformed to a thermally stable form as the temperature exceeded about 70°C. At about pH 2.8, gelation temperature increased with pectin concentration to about 0.85% after which no change in gelation temperature was observed. On cooling, 75–85% of the gel strength attainable on standing overnight was developed within 30 min, providing for possible development of a rapid test method for determining pectin gel properties.

Time–intensity evaluation of sweetness and fruitiness and their interaction in model solution

Using a computerized time–intensity (TI) system, ten judges evaluated sweetness and fruitiness of 24 aqueous solutions varying in concentrations of glucose (0–9% w/v) and peach extract (0–0.6% v/v) and presented at two solution temperatures (5 and 25°C). The TI curves were quantitated using 11 parameters. For sweetness, 10 TI parameters increased with increases in glucose concentration; a further increase was observed in seven parameters with increases in peach extract concentration and increases in solution temperature. For fruitiness, seven TI parameters increased with increases in peach concentration; a further increase was elicited in four TI parameters with increases in glucose concentration. The suitabilty and interrelationship of these parameters for characterization of the TI responses was discussed. Although the total persistence of the two attributes did not differ, the mean time to maximum sweetness (6.6 s) was 3.8 s shorter than that found for fruitiness (10.4 s). For stimuli that were generally not recognized to have lingering aftertastes, sweetness and fruitiness had 74 and 65%, respectively, of the total perception after the maximum intensity.

Evidence for adsorption mechanism of flavor perception

Time–intensity (TI) methodology was used to explore adsorption–desorption as the 'model' for chemoreception. Temporal perception of sweetness and fruitiness was evaluated for 24 aqueous solutions varying in glucose (0.0–9.0% w/v) and peach essence (0.0–0.6% v/v), presented at two solution temperatures (5 and 25°C). The resulting TI curves were characterized using four TI parameters: maximum intensity, time to maximum, maximum rate of onset (adsorption), and maximum rate of decay (desorption). As predicted from adsorption–desorption principles, the time to maximum was concentration-dependent for low-stimuli concentrations and became concentration independent at higher concentrations. The maximum rates on onset and decay of perception were proportional to stimuli concentration for both sweetness and fruitiness. By comparing adsorption with desorption for each attribute, an index of the efficiency of stimuli removal was calculated. The efficiency of stimuli removal decreased exponentially with increasing stimuli concentrations.

ENTOMOLOGY–PLANT PATHOLOGY

Apple replant disease control by biological treatment

Recently, apple replant disease (ARD) has become a major concern to the growers of the Okanagan, Similkameen, and Kootenay valleys of British Columbia. Chemical control with soil fumigants is a popular means to control ARD. The effectiveness of volatile fumigants is influenced by temperature and moisture. The application of fumigants is also difficult, expensive, and hazardous. Moreover, soil fumigation results in destroying the natural equilibrium between pathogens and antagonistic microorganisms. The purpose of this study was to evaluate biological treatment, in combination with fumigation and fertilization, for the control of ARD in the Okanagan valley of British Columbia. The test was conducted at Kelowna on an old apple

orchard site. A 3-year study indicated that the application of strain EBW-4 of *Bacillus subtilis* as a soil drench application at the time of planting was effective in promoting tree growth on replant soil. The application of monoammonium phosphate (11–55–0 NPK) or fumigation with formalin did not increase trunk diameter or shoot growth of apple trees.

Control of the grape erineum mite during the growing season

The grape erineum mite, a major pest on susceptible grape varieties, was controlled effectively during the growing season by a new sulfur formulation that is primarily a fungicide for powdery mildew suppression. One or two sprays of Kumulus S 80 WP (80% sulfur) were applied by airblast sprayer providing a.i. at 2.7 kg/ha. In a 4-ha block of Verdelet grapevines the number of vines infested with mite erinea on the foliage was reduced from 99.9 to 1.2% by spraying 19 May at prebloom, immediately after the first evidence of erinea development was detected, and again 15 July at mid season. In a 4-ha block of Vidal 256 the number of infested vines was reduced from 88.4 to 13.4% with one spray applied 1 June, at prebloom about 14 days after the first evidence of erinea on the leaves was observed. Levels of mite infestation in each block were determined by inspecting for active mite erinea on the foliage of 1000 vines in marked plots. Pretreatment infestation levels were determined prior to harvest (24 September 1987) and posttreatment levels in mid season (July 14) and prior to harvest (27 September 1988). Previously available sulfur formulations with or without added surfactants have been, at best, marginally effective against heavy infestations of the grape erineum mite when applied during the growing season. Various acaracides and systemic insecticides evaluated in earlier trials also were ineffective.

Codling moth control by sterile-insect release

Implementation of a sterile-insect release (SIR) program would bring about a major shift in control of codling moth, from chemical to biological control. In cooperation with the Summerland Research Station, the B.C. Fruit Growers' Association (BCFGA), the largest fruit cooperative in the Okanagan, reappraised the commercial cost and practical feasibility of an area-wide SIR program. The projected program cost to orchardists is equal to, or less than, the cost of chemical control, and all property owners would also pay a small fee. In 1988 the BCFGA approved the program without a dissenting vote and has requested the support of the various levels of government in the area to implement the program.

The effect of a codling moth SIR program on the control of other insect pests of apples and pears was assessed. Some pests would diminish in importance, because of increased action of beneficial organisms with the reduced application of insecticides, but a few species might increase in importance. These species could, in most cases, be controlled by treatments applied in the spring before codling moths would be released, and in the remaining cases chemicals or application procedures would be selected to be of minimal toxicity to the released sterile moths.

Role of nematodes, fungi, and bacteria in apple replant disease

Apple replant disease (ARD) is one component contributing to the poor growth of apple trees planted on old apple or pear orchard sites. This disease suppresses initial growth of young trees and reduces yield. A number of biotic and abiotic causal agents have been identified. Abiotic causal factors include imbalanced nutrition, especially low phosphate, low or high pH, poor soil structure and drainage, cold or drought stress. Nevertheless, because of the control obtained with soil fumigation or pasteurization or both, the cause of ARD is thought to be biotic. The purpose of this investigation was to test the response of apple seedlings to nematodes, fungi, and bacteria both individually and in combination, to determine their role in ARD in soils of the Okanagan valley.

The growth of apple seedlings (McIntosh), dry root weight of seedlings, and root score were reduced when soil in the test pots was inoculated with 210 or 322 *Pratylenchus penetrans* per 50 cm^3. However, fungi or bacteria in combination with high levels of *P. penetrans* (322 per 50 cm^3) did not decrease the plant growth. Apple seedlings were stunted and their dry root weight was reduced when grown in sterilized soil to which *Penicillium janthinellum*, *Constantinella terrestris*, *Trichoderma* sp., and four strains of *Bacillus subtilis* previously isolated from ARD soil were added. *Trichoderma* sp., B1, and B26 strains of *B. subtilis* alone

reduced the plant growth but the combinations of *Trichoderma* sp. + B1 and *Trichoderma* sp. + B26 increased plant height. It is suggested that either fungi, bacteria, and nematodes alone, or their interactions, may contribute toward the occurrence of ARD in orchard soils of the Okanagan valley of British Columbia.

POMOLOGY AND VITICULTURE

Hormonal physiology and apical form of four strains of McIntosh apple

Shoot tips collected in June from Summerland Red McIntosh, the standard nonspur strain, and from three other strains of McIntosh varying from spur-type (MacSpur and Morspur) to very compact and spurry (McIntosh Wijcik) were examined for polar and less-polar gibberellins (GAs) and for cytokinin-like bioactivity. McIntosh Wijcik also differs from the other strains in that it exhibits a very columnar growth habit with few lateral branches emerging from the main stem.

Although total gibberellin bioactivity did not differ among strains, McIntosh Wijcik exhibited significantly lower levels of the more-polar gibberellins (GA_1 and GA_{19}) than any other strain. These are the gibberellins believed to be most directly involved in shoot extension.

Conversely, cytokinin bioactivity (believed to be predominately zeatin and zeatin riboside) was very high in shoot tips of McIntosh Wijcik compared to the other strains. High cytokinin activity is consistent with the strong tendency of McIntosh Wijcik to develop growing points (in this case, spurs) at virtually every node on 2-year-old wood.

It is concluded that the combination of high cytokinin and low-polar gibberellin activity plays an important role in defining the unique, and heritable growth habit of McIntosh Wijcik apple. It is significant, however, that the other spur-type strains differed little from Summerland Red McIntosh in their hormonal physiology.

Effects of vineyard site and canopy manipulation on growth, yield, and fruit composition of Gewurztraminer vines

Gewurztraminer vines in a Kaleden, B.C., vineyard were subjected over the 1985–1987 seasons to seven different canopy treatments: Unhedged control (C); cluster thin (CT); postbloom hedging (H); hedge + paclobutrazol (H + P); basal leaf removal (LR); lateral shoot removal (LSR); and CT/H + P/LR (REM-ALL). Hedging, LSR, and LR reduced degrees Brix and some parameters of juice color in 2 of 3 years, whereas LR also reduced titratable acidity (TA) and pH. Free volatile terpene (FVT) concentration was improved in 1987 by LR, and in 1986 in CT, H, H + P, and REM-ALL vines. Potential volatile terpene (PVT) concentration was also increased over the C treatment in CT, H, LR, LSR, and REM-ALL vines in 1986 and in LR and REM-ALL vines in 1987. Treatments in which leaf area was removed (H, H + P, LR, LSR, and REM-ALL) generally exhibited lower pruning weights, yield, cluster weight, berry weight, and berries per cluster than C and CT vines. Periderm development was not strongly affected by any treatment. Paclobutrazol (a plant growth retarding chemical) successfully reduced the length of lateral shoots on H + P and REM-ALL vines. This phenomenon was confined to the upper portion of the canopy.

The experiment was modified in 1988 to test the effects of vineyard site and canopy manipulation on canopy density and monoterpene concentration of Gewurztraminer berries, juices, and wines. Three canopy treatments, C, H, and LR, were applied to vigorous, bilateral, cordon-trained vines at each of three sites. Average degree-days (in degrees Celsius) varied between the sites in 1988 from 1055 (Kelowna) to 1390 (Oliver). Canopy density was reduced at all sites by H and LR treatments. The Kelowna site was characterized by highest cluster weight and clusters per shoot, and lowest degrees Brix, TA, and pH. Highest FVT and PVT were found in the berries and juices from the Kelowna site. Canopy treatments had no effect on yield parameters, degrees Brix, or TA. The LR treatment increased FVT and PVT in the juice and PVT in the berries, whereas both the H and LR treatments decreased juice pH. The effect of LR on increasing juice FVT was only apparent at the moderate heat unit site (Kaleden) where canopy density was high. Mechanical LR at the Kelowna site resulted in higher berry FVT and lower pH than manual LR, but juice FVT and PVT were lower also.

Effects of methyl bromide fumigation on apple quality

Apples were treated with methyl bromide for disinfestation of codling moth, a quarantine requirement for potential export of apples to Japan. Research over 4 years indicated a high, moderate, and low tolerance to the fumigant for Golden Delicious, Red Delicious, and Spartan apples, respectively. Incidence of external and internal disorders increased in most instances with longer storage periods after treatment; 4-h treatments were more detrimental to the fruit than 2-h treatments. Dips in diphenylamine (DPA) reduced but did not prevent disorders. Fumigation had little effect on firmness and no effect on soluble solids content or titratable acidity. Treatments with a low risk of disorder development are 32–64 g/m^3 for Golden Delicious, 32–48 g/m^3 for Red Delicious and 32 g/m^3 for Spartan, all at 10°C for 2 h.

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Departure

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INTRODUCTION

This 26th annual report of the Vancouver Research Station summarizes some aspects of our research program. It emphasizes our dual mandate, first as national centre for plant virus research and plant health biotechnology, and second in our function of assisting growers of vegetables and small fruits in British Columbia, particularly in the control of pests and diseases. The latter activity has led to an outstanding program of integrated pest management that has already resulted in a decrease of chemical pesticide applications on several crops.

The recruitment of new young scientists to replace those retired is proceeding on schedule to give us an excellent group of plant virologists and molecular biologists. Their research is aimed at controlling viral diseases in economically important crops through the use of the new recombinant DNA technology, while developing new and sensitive tools for accurate diagnosis of viral, bacterial, and fungal diseases.

Further details of research, and reprints of this report or of the publications listed can be obtained either from the scientists or from the Director, Research Station, Agriculture Canada, 6660 N.W. Marine Drive, Vancouver, B.C. V6T 1X2; Tel. (604)224-4355.

M. Weintraub
Director

VIRUS CHEMISTRY AND PHYSIOLOGY

Biotechnology

The complete nucleotide sequences of the genomes of two cucurbit-infecting, fungus-transmitted plant viruses, cucumber necrosis (CNV) and melon necrotic spot (MNSV), have been determined. The deduced genomic organizations of CNV and MNSV differ, which is consistent with their assignment to different taxonomic groups. However, comparisons of the predicted protein products of these viruses demonstrate considerable similarity of amino acid sequence in their coat proteins and putative replicases. Full-length cDNA clones of RNA in CNV, from which infective RNA can be transcribed, are being used to study regions of the CNV genome involved in transmission by the fungus vector (*Olpidium radicale*) and disease induction.

The sizes and genomic locations of RNA-directed in vitro translation products for CNV are being determined by hybrid-arrest translation and synthetic CNV transcripts. Viral RNA directs the synthesis of four major proteins in wheat germ extracts (M_r = 33 000, 41 000, 21 000, and 20 000). The 33 000 protein maps to the 5' terminus of the genome, the 41 000 to an internal location, and the 21 000 and 20 000 proteins to the same location at the 3' terminus of the genome. The sizes of these proteins and the genomic locations of the coding sequences determined from in vitro translation studies are consistent with that based on nucleotide sequence data. However, no synthesis of a 92 000 readthrough protein, predicted from the nucleotide sequence, has been observed.

Complementary DNA clones of both genomic components of the bipartite nepovirus, tomato ringspot, have been prepared and preliminary nucleotide sequences of the 3' termini of RNA-1 and RNA-2 have been determined. A previously detected 1.9-kilobase region of homology between RNA-1 and RNA-2 was confirmed.

Double-stranded cDNA copies of the cucumber mosaic virus (CMV) gene for the non-structural protein 3A was inserted in an expression vector containing the protein A gene from *Staphylococcus aureus*. Using the fusion protein expressed in *Escherichia coli* as an immunogen, monoclonal antibodies were produced that reacted with the 3A protein produced by in vitro translation of CMV RNA. These antibodies were used to detect the accumulation of the 3A protein, primarily in the nucleolus, by electron microscopy of immunogold-labeled, ultra-thin sections of CMV-infected tobacco leaf cells.

Mixed virus infections

A flexuous virus, isolated from white cockle (*Silene pratense*) naturally co-infected with ribgrass mosaic virus, was shown to be a new

member of the potexvirus group. Infectious, purified preparations contained 546- and 204-nm nucleoprotein rods consisting of 6.9 or 2.4 kilobases polyadenylated, single-stranded (ss) RNAs and a 29 000 capsid protein. Double-stranded (ds) RNAs of 17.1-, 7.0-, 5.7-, and 4.6-kilobase pairs were isolated from infected plants. In vitro translation products of viral ss- or ds-RNAs reacted with antiserum specific for the virus. Hybridization studies with the new virus showed no nucleotide similarity with seven other potexviruses, including potato virus ×, white clover mosaic, and clover yellow mosaic. The virus, provisionally named white cockle virus × is more closely related to narcissus mosaic virus than to nine other potexviruses.

Further data were obtained on the interaction of the cowpea strain of southern bean mosaic virus (SBMV-C) and sunn-hemp mosaic virus (SHMV) in bean, a nonpermissive host for SBMV-C. Protoplasts, isolated from Bountiful bean and inoculated in vitro with SBMV-C, sustained excellent replication of infectious virus as determined by ELISA and infectivity assay, indicating the innate susceptibility of protoplasts from a nonpermissive host. Spread of SBMV-C occurred in inoculated primary leaves of Bountiful bean simultaneously inoculated with SHMV but, in contrast to SHMV, SBMV-C does not proceed to the petiole, suggesting that long-distance transport of SBMV-C is not facilitated by co-infection with SHMV. These results are in contrast to those obtained with similar helper-dependent virus combinations.

Effect of flavenoids on virus infectivity

Naturally occurring derivatives of the flavenoid quercetin (3,3',4,5,7-pentahydroxyflavone) have been screened as possible antiviral compounds. Preliminary experiments showed that in vitro incubation with 3,7-dimethoxyquercetin (9 and 90 µg/mL) inhibited infectivity of tobacco mosaic virus (TMV) on *Nicotiana glutinosa* by 50%. The 4',7-dimethoxy and 3-methoxy-substituted derivatives were without effect over the range of 0.9–90 µg/mL. Pre-incubation of TMV with both 3,3'-diSO_4 quercitin and 3,7,4'-triSO_4 quercetin enhanced infectivity by 25–50%, depending on concentration.

PLANT PATHOLOGY

Nematology

Small fruits. The growth of raspberry plants was much reduced by the root lesion nematode *Pratylenchus penetrans* in field microplots, when plant densities were more than 50 per 50 mL of soil at planting time. No noticeable damage occurred when soil nematode densities were low at planting. When the fungus *Phytophthora erythroseptica* was present in the microplots, plant growth reduction was severe at all nematode densities. Nematodes reproduced faster in raspberry roots in the presence of the fungus in the microplots but not in the greenhouse.

Biological control. A survey of the parasitic and predatory mycoflora of British Columbia soils was started. Fungi predatory and endoparasitic to nematodes were found in 50 of 81 samples taken from 41 sites in the agricultural soils of the lower Fraser Valley. Four species were isolated in pure culture: *Dactylaria* sp., *Arthrobotrys* sp., *Meria* sp., and *Hirsutella* sp. Greenhouse and microplot experiments will determine the potential for use of several of these fungi.

Bacteriology

DNA probes were produced for detection of *Erwinia carotovora*. Two probes were selected from a genomic library of *E. carotovora* in the Bluescribe plasmid vector. One probe, 2 kilobases in length, was obtained by selecting *Erwinia* DNA segments not found in *Escherichia coli* strains HB101, RR1, or DH5α. Another probe, 6 kilobases in length, was selected because *E. coli* DH5α transformants containing this segment of *Erwinia* DNA were able to grow on crystal violet pectate medium, which is selective for pectolytic *Erwinia*. The probes were labeled with ^{32}P using a random primer and then used to probe lysed colonies or purified DNA of various *E. carotovora* strains fixed to Zeta-probe membranes. Both DNA probes hybridized to 40 strains from different serogroups as well as to 20 strains selected from an international culture collection in Belgium. Both subspecies, *carotovora* and *atroseptica*, were included among the strains. Subsequently the 6-kilobase probe was subcloned and two smaller inserts of 1 and 2 kilobases were selected. Both subclones hybridized to varying degrees with all

E. carotovora strains tested to date. Analysis of restriction fragment length polymorphism of several strains in serogroups I, III, and XVIII with the 6-kilobase probe revealed that, whereas restriction patterns were identical among some strains within a serogroup, differences in pattern within a serogroup also occurred.

Fungal pathology

Monoclonal antisera have been developed that react differentially against the 10 described North American races of *Phytophthora fragariae*, the causal agent of red stele of strawberry. In a comparative indirect ELISA test using seven of the hybridoma clones it was possible to identify each of the 10 races, with the exception of races 3 and 6 that have identical reactions to all antisera.

The fluorescent antibody technique has been used successfully to detect *Phytophthora erythroseptica* in inoculated raspberry roots and *P. fragariae* in inoculated strawberry roots using a Phytophthora-specific polyclonal antiserum. Detection in field-infected samples was less successful, possibly because of low concentration of fungal mycelium resulting from age of infection.

A collection of 123 clones of *Fragaria chiloensis*, obtained along the coast of British Columbia, were evaluated for resistance to a mixture of races of *Phytophthora fragariae*. Nine clones were immune to the composite of races (A1, A2, A3, A4, and A5) and a further 23 clones were highly resistant. These clones form an important pool of resistance genes available for strawberry breeding.

Virology

Blueberry. A carlavirus, designated blueberry scorch virus (BBScV), has been shown to cause a scorch disease of highbush blueberry. During a survey of blueberry fields in British Columbia, Washington, and Oregon, BBScV was found to be restricted to the Puyallup Valley in Washington. However, there were scorched blueberry bushes in all areas surveyed that did not react with our BBScV antiserum in double antibody sandwich ELISA. Purification from these bushes using the BBScV protocol was unsuccessful, suggesting that another causal agent induced scorch symptoms. Flowers from some of these bushes in one field were used as inoculum for mechanical transmission to *Nicotiana clevelandii*. Purification from the *Nicotiana* plants yielded spherical particles when observed with the electron microscope. A host range was conducted with this isolate and only three species of *Nicotiana*-produced symptoms. An antiserum against the spherical virus has been developed and will be used to determine the distribution of the virus.

Raspberry. Previous work had revealed the presence of double-stranded RNA (dsRNA) in native red and black raspberry plants in British Columbia. None of the suspect plants showed symptoms, but the dsRNA pattern was indicative of virus infection. Thin-section electron microscopy of leaf tissue showed no evidence of virus-like particles. Seed collected from *Rubus leucodermis* and *R. strigosus* produced seedlings that had the same dsRNA banding pattern. The bands were detected in 30 of 52 *R. leucodermis* and 5 of 18 *R. strigosus* seedlings that were assayed. Random-primed cDNA made from the major dsRNA band hybridized to total DNA isolated from *R. leucodermis* and *R. idaeus* that did not contain dsRNA band, indicating that the dsRNA band was of host rather than viral origin. These results raise some questions about the value of the dsRNA technique as a procedure for the detection of latent viruses in nuclear stock programs.

Asparagus. In previous surveys of British Columbia asparagus plantings, we determined that asparagus virus 2 (ilarvirus) was prevalent and that asparagus virus 1 (potyvirus) was present but the incidence was considerably lower. Tobacco streak virus (TSV), which is known to infect asparagus in Europe and the United States, was not found primarily because our detection techniques were not sufficiently sensitive to distinguish asparagus virus 2 from TSV. Both are ilarviruses and induce similar symptoms on indicator plants and the polyclonal antiserum against TSV that was available at that time was of poor quality. This problem has been solved by the production of high-quality monoclonal antibodies against TSV. In the 1988 season, we used the ELISA technique to index 705 asparagus samples from commercial plantings in the Okanagan Valley, of which 408 were infected with asparagus virus 2 and 32 were infected with TSV.

Potato. Murine monoclonal antibodies (MCAs) prepared against beet western yellows virus (BWYV) and potato leaf roll virus (PLRV) reacted strongly with the homologous virus but exhibited no cross-reactivity when used in

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heterologous tests. Assays were done using a triple antibody sandwich ELISA procedure; polyclonal antibodies for coating, MCA as the second antibody, and rabbit antimouse alkaline phosphatase as the conjugate. From 1986 to 1988, 771 potato plants with symptoms of potato leaf roll disease, representing 26 cultivars, were tested. Samples were collected from 6 Canadian provinces and 12 states, mainly at the Florida and California winter test plots. None of the samples tested positive for BWYV, 754 tested positive for PLRV, and 17 samples tested negative for both viruses in aphid transmission tests using *Myzus persicae* as the vector and *Physalis pubescens* as an indicator plant. The results indicate that BWYV is not a common component of potato leaf roll disease in North America—indeed it may be rare.

Small fruit breeding

Raspberry. Two B.C. raspberry selections, 80-28-53 and 80-28-50, both from the cross of Nootka × Glen Prosen, were identified in 1987 as warranting immediate propagation. They continued to perform well in 1988 in first test plots at the Vancouver Substation. 80-28-53 again was noted for its large (mean weight 5.4 g), attractive, bright red fruit, which is exceptionally well presented. 80-28-50 also has good presentation of large fruit. The mean weight of 4.3 g is similar to Comox and 1.0 g heavier than Willamette. Fruit of 80-28-50 is not quite as bright or glossy as that of 80-28-53 but it is firmer and still attractive enough for the fresh market. In addition the fruit seems particularly well suited to machine harvest. Both selections have consistently outyielded the standard cultivars, with the exception of Comox, and have extended harvest seasons. In 1988, harvest of 80-28-53 started July 4 and continued for 53 days; harvest of 80-28-50 started July 12 and continued for 45 days. Both selections are aphid resistant and thus will escape the mosaic virus complex and, to date, neither has become infected with the pollen-transmitted raspberry bushy dwarf virus. 80-28-50 has shown an extended shelf life, which suggests resistance to postharvest rots. Both are relatively susceptible to spur blight and cane *Botrytis*.

Both selections have been released to propagators; a few plants of 80-28-53 should be available for grower trials in 1989 and of 80-28-50 in 1990.

ENTOMOLOGY

Vectors

Aphid survey. New records brought the number of known aphid species in British Columbia to 397. Aphids have now been collected from 1052 different host plants and the total number of aphid–host plant associations is 2043.

Spread of virus diseases. A rapid but accurate method for sampling strawberry aphids, *Chaetosiphon fragaefolii*, was developed for use by growers and professional pest management consultants in an integrated pest management program for strawberries. Sampling consists of recording only the proportion of strawberry leaves *not* infested with aphids. The proportion and the sample size permit the abundance of aphids in a field to be estimated from statistical relationships developed from sampling commercial strawberry fields. Sufficiently accurate samples can be made in the field within minutes as compared with hours if all aphids were to be counted.

The 3rd of a 4-year survey for PLRV and BWYV was conducted in the lower Fraser Valley of British Columbia. The main source of PLRV was again verified to be backyard gardens, with no incidence of PLRV or BWYV being detected in samples from growers' fields.

Pest management

Ermine moth (Yponomenta malinellus). *Ageniaspis fuscicollis*, a European parasite first released in 1987, was reared from ermine moth larvae collected at the release site this year. The recovery of the parasite is a positive indication of a potentially successful biological control program. Additional releases of the parasite were made this year.

Aphid and virus regulation in strawberry. The efficacy of oxydemeton-methyl (Metasystox-R 2.4 SC) was evaluated for the control of the aphid *Chaetosiphon fragaefolii* and the regulation of viruses on Totem strawberries, *Fragaria* × *ananassa*. Analysis of aphid data collected during 1987 and 1988 suggested that aphid numbers in the controls were two to three times higher than in plots treated with the American rate of oxydemeton-methyl. Virus indexing during July and August, 1987, indicated that 21% of the parent plants were infected with viruses and that these were scattered randomly with respect to pesticide

treatment. Indexing during 1988 suggested that 67–100% of the plants in a plot were infected with viruses, and that the percentage infected was negatively related to the pesticide application rate. Yields in the first harvest year were 25% less in the controls than in plots treated with the American rate of oxydemeton-methyl. The results suggest that the use of oxydemeton-methyl in commercial strawberry fields will effectively reduce aphid populations and the proportion of plants infected with viruses.

Greenhouse pests. Experiments were conducted in a cucumber greenhouse to determine the color preferences of the western flower thrips, *Frankliniella occidentalis*, a new and major pest of greenhouse vegetables. Traps painted bright blue, violet, yellow, and white were all found to be attractive colors, with a slightly desaturated blue tint being a very potent visual lure.

Potato pests. Several granular insecticides were evaluated for efficacy and longevity against first and second generation tuber flea beetles, green peach aphids, and potato aphids. The insecticides were tested at two or three rates at three locations with differing soil types. Only insecticides with systemic properties controlled both pests. Of the registered products tested, Temik (aldicarb) gave the best control of all pest species in soils with low organic matter. Thimet (phorate) provided similar levels of control on all but green peach aphids. Efficacy of these chemicals was significantly reduced in soils with high organic content.

An expert system to provide potato growers with field-specific late blight predictions (blight management system or BMS) was evaluated successfully for the 2nd year. BMS rapidly and efficiently processes weather data collected automatically or manually from the field, and the expert system software provides recommendations to growers. In pilot studies, BMS has enabled growers to reduce fungicide spraying by at least 50%.

Insect virology. A new research program has been initiated that will investigate the molecular biology of baculoviruses. The general aims of this biotechnology program are directed at understanding the molecular mechanisms of virus infection to determine strategies of improving these viruses as biocontrol agents. Baculoviruses have the potential to replace chemical insecticides in some insect control programs, and their use will therefore help to reduce the use of compounds that may be toxic to the environment.

Early studies identified a potential immediate early gene of the *Orgyia pseudosugata* nuclear polyhedrosis virus using a related gene from the *Autographa californica* nuclear polyhedrosis virus. This gene now called OpIE-1 has subsequently been cloned and sequenced. OpIE-1 may be one of the limited number of genes that are expressed as soon as the virus enters the cell of the target host insect. These genes turn on other viral genes and are therefore usually essential for viral replication. This gene and other similar genes may provide information on how to engineer these viruses genetically to improve their effectiveness as biological insecticides.

Pests of small fruits. Winter moth, *Operophtera brumata*, has been positively identified as a pest of blueberries and raspberries in the lower Fraser Valley. This insect was cited by growers as the single most important pest on blueberries, and the problem appears to be increasing. Several experiments were conducted to determine the suitability of the Tachinid fly *Cyzenis albicans* for control of winter moth on blueberries. This fly lays eggs on foliage, which the host larva then ingests, and has been observed to cause up to 70% mortality of winter moth on apple trees. On blueberry, the fly was able to distinguish differing levels of damage and to concentrate attacks on the foliage where winter moth larvae were feeding; this pattern was not observed on raspberry. Results suggest that *Cyzenis* may be a useful control agent on blueberry but not raspberry.

Experiments were conducted to determine the suitability of alternate plants as monitoring tools for the cranberry girdler, *Chrysoteuchia topiaria*. This insect is difficult to monitor without the destruction of valuable cranberry vines, and so a "trap" crop or monitor crop might be used to more easily evaluate insect abundance. Eight alternative plants were assessed: one species of tree seedling—Douglas-fir; and seven grasses—red fescue, biltjart fescue, sheep fescue, timothy, reed canarygrass, foxtail, and redtop. Greater numbers of girdler larvae were detected on foxtail than on any of the other plant species, indicating a preference for foxtail by either the ovipositing female or the feeding larvae.

Residue chemistry

Persistence of vinclozolin. When pea leaflets were treated with the fungicide Ronilan 50 WP (50% vinclozolin) or an acetone solution of vinclozolin, the persistence of the fungicide under laboratory conditions was higher with Ronilan 50 WP, a commercial formulation, than with an acetone solution. However, most of the Ronilan deposits were easily dislodged by rinsing with water, indicating that Ronilan would be susceptible to weathering. The dissipation of vinclozolin on leaflets was linear and the calculated half-life was 33 days for Ronilan and 13 days for the acetone solution. Translocation of vinclozolin was not detected in pea plants after its application to one of the leaflets; and none of the hydrolytic degradation products was detected in the treated plants. To ensure seasonal protection against fungal infection with Ronilan, its application must be properly timed and several treatments may be required.

Residues of phorate in potato. Thimet 15G (15% phorate) was evaluated as an alternative to Temik 15G (15% aldicarb) for control of tuber flea beetle, *Epitrix tuberis* Gent., and green peach aphid, *Myzus persicae* Sulz. Phorate was comparable to aldicarb in efficacy. It provided effective control in a sandy loam soil and a clay soil but was inadequate in a muck soil with organic matter content as high as 58%. Phorate strongly adsorbed on soil with higher organic matter and much less of the chemicals were picked up by the plants, thus reducing its efficacy. Potatoes picked up phorate residues including its toxic oxidative metabolites, most readily from sandy loam, more readily from clay and least readily from muck. Potatoes grown in sandy loam soil contained about 0.1 ppm (fresh weight) residues 83 days after application of phorate at an a.i. rate of 3.2 g/10 m of row.

Residue of oxydemeton-methyl in strawberry. Metasystox-R 2.4 SC (24% oxydemeton-methyl) was evaluated for the second time for control of strawberry aphid, *Chaetosiphon fragaefolii* (Cockerell). The insecticide was applied at a.i. rates of 0.28, 0.56, and 1.12 kg/ha at the start of bloom. Fruit was analyzed after 39 and 46 days. Residues were well below the negligible level of 0.1 ppm (fresh weight) for all application rates tested. Registration of Metasystox-R 2.4 SC as an alternative to Systox is currently under review by the Minor Use of Pesticides Program.

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